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EDITORIAL

The Textile Associations' Institute*

THE "Textile Associations' Institute" is not a new organization. It was organized in 1930 by twenty-two of the industry's leading national associations. Delegated representatives of these associations were its preliminary directors and officers. They were responsible for its permanent organization Nov. 6, 1930, "to promote, cultivate and facilitate scientific research . . . in the textile manufacturing industries of the United States."

Since the date of the Institute's organization, and until very recently, the associations which were responsible for its birth, and the individual members of those associations who are also members of the Institute, have been too busy with problems confronting their individual industries to give the needed support to plans designed to benefit the whole industry co-operatively. In but few instances have the services of this Institute been utilized thus far by these associations as associations.

Meantime the Institute has attracted to its membership groups of individuals, each of which group forms a representative cross-section of each of the leading national textile associations which were responsible for its organization in 1930. Now that business is apparently on the road to recovery, and the industry's normal need of scientific and economic research has been increased by an adventure into the uncharted field of N. R. A., it seems high time for these associations to exercise their parental prerogative, and to demand of this Institute the services for which it was organized to provide them.

In anticipation of such demands recent meetings of the board of directors and of the research committee of the United States Institute for Textile Research, Inc., were devoted to discussion and perfection of plans in this connection. Briefly, they cover

* See Co-operative Research P. 261.

(*Continued on page 262.*)

Elastic and Plastic Properties of Textile Fibres

Part 1.—The Stress Strain Relation in Textile Fibres: Review of Literature; Experimental Procedure; Discussion of Results

By RAYMOND L. STEINBERGER *

Abstract

X-RAY data arranged in the light of chemical facts have given us some very clear ideas as to the ultimate molecular and crystalline (micellar) structure of the main constituents of textile fibres: cellulose and cellulose derivatives in cotton, ramie and the rayons; keratin in wool; fibroin in silk. Experimental and theoretical details are not yet developed fully enough for reliable fibre strength computations to be made from molecular and crystal data. Plastic flow in micellar systems (textile fibres) is compared with plastic flow in polycrystal bodies (metals).

A description is given of a simple tension gauge by means of which the stress strain relation in single fibres several cm. long may be obtained. A tension device, read by means of a telescope and scale, enables one to read the tension quickly and accurately. The range of the gauge is readily adjusted. A new type of fibre clamp is described. The humidity of the atmosphere about the specimen is controlled by means of an air stream flowing slowly through H_2SO_4 solutions. The stress computations are based on an area of section measured on each fibre only a few mm. removed from the length tested. The fibre was sectioned and sketched with a microscope and camera lucida arrangement. Because there is considerable plastic flow in fibres for a few seconds after the tension is applied the usual constant rate of loading method was not used. A period of rest (½ minute) after each loading was used

* Mr. Steinberger is a Senior Fellow of the Textile Foundation working under the direction of Dr. P. W. Bridgman, Harvard University, Cambridge, Mass.

before the tension and elongation were read. During the half minute relaxation period a condition of relative rest in the material of the fibre is attained. The resulting stress strain curve is reproducible and quite characteristic of the fibre. The rayons (Celanese, viscose, nitro-cellulose, Bemberg cuprammonium) and the natural fibres (silk, Egyptian cotton, merino wool, ramie) were tested. In the rayons there is an initial linear portion obeying Hooke's law followed by a long region of plastic flow. Silk and wool are wholly plastic with no linear region under the conditions specified. Cotton is linear throughout. Ramie was too strong for the tension gauge and was not stressed to the ultimate.

Conclusions

ACCORDING to the type of stress-strain curve the fibres fall into three classes: (*a*) Natural cellulose fibres (cotton and ramie); (*b*) regenerated cellulose or cellulose derivatives; (*c*) fibres of animal origin. The natural fibres exhibit much the greater strength. The region of proportionality between stress and elongation extends to high stresses, and the plastic yield, which will be examined in future tests, will probably be found to be small. The micelles are well oriented parallel to the axis in the case of ramie, and spirally about the axis in the case of cotton. The uniform arrangement of micelles indicates improved strength. In class (*b*) the micelles are apparently not well oriented and begin to flow and orient themselves parallel to the fibre axis at a stress much lower than in the case of the natural fibres. There is a long range of stress in which micelle flow and plastic yield take place. In the animal fibres silk and wool (*c*) both plastic and elastic yield apparently take place at the same time.

In the case of wool it has been suggested by Astbury and his co-workers [7, 8, 10, 11] that wool possesses elastic properties of a type entirely different from that of cellulose. (See also Speakman [12, 13, 14, 15].) Hair and wool can be stretched enormously and recover their initial length, or even shrink in the presence of moisture or steam on release of tension. Wool and hair exhibit two molecular forms of the basic constituent keratin—α keratin in the unstretched condition, β keratin in the stretched condition.

Reversible transformations from one type to the other can be made. The α molecular form is indeed a chain of several links, somewhat like the cellulose principle valence chain, but, unlike the cellulose chain, which is intrinsically very strong and preserves its form under stress, the α keratin molecule apparently extends axially under stress, with an opening out of the separate links to form a long zig-zag polypeptide chain of β keratin, wherein two links of α keratin (identity period 5.15 Å) are stretched out into a chain six times as long.

In the case of the cellulose fibres it would be expected that, before yield by micelle slip, the principal valence chains, which are nearly parallel in the micelles supporting the tension, will extend with a straight stress-strain curve such as one would get with but a single chain. On the other hand, in wool there is considerable plastic resistance to extension because each link in opening out is considerably impeded by its lateral neighbors. To get the full extension of wool it is necessary to reduce this lateral interference by the use of moisture or steam.

The tension experiments are being extended to include the other textile fibres at the standard humidity of 50%. Experiments at various humidities will also be performed. More precise methods for the determination of cross-section area are being developed.

This report covers the first half of the present project and will be included in the final comprehensive report, in which will be given a more thorough and mature consideration of the elastic and plastic properties than that given in this discussion.

Review of Literature

OUR knowledge of the structure of both natural and artificial fibres has been so greatly extended in recent years, mainly through the use of x-ray methods, that we are now in a position to make a more profitable study of their mechanical properties. A rational explanation can now be built up for their elastic and plastic behavior. At the beginning of this work the various rayons were chosen for the experiments because of apparent simplicity of structure. The simplicity is, however, merely superficial in that the fibres can be obtained in any desired length of single filament, they possess no kinks, the section area and shape are preserved constant throughout lengths great compared with the few centimeters required for the experiments. When an attempt is made to relate mechanical properties to fibre structure, it is readily seen that the natural fibres possess a much more fundamental simplicity of structure, if simplicity of structure

may be considered as synonymous with ordered arrangement of atoms, wherein the macroscopic body can be defined with precision as the ordered repetition of a small unit of structure.

The fibre which exhibits the greatest uniformity of structure is ramie, and has consequently been used very extensively in the work on the structure of cellulose, of which it is a very pure natural specimen. The work of K. H. Meyer,[1] H. Mark,[2] G. L. Clark,[3] R. K. Andress,[4] and many others listed in the bibliographies of [2] and [5] have brought our knowledge of the structure of cellulose to such a stage that we can say with confidence that the crystalline structure of cellulose is as well known as that of any substance. The structure of the animal fibres has not been so well worked out, but much interesting information has already been obtained by W. T. Astbury and his co-workers [6, 7, 8, 9, 10, 11] and J. B. Speakman [12, 13, 14, 15, 16].

Crystalline Structure of Cellulose

A brief summary of the evidence for the micelle or crystalline structure of cellulose fibres will be given here. The x-ray photograph obtained when a monochromatic beam, say the K α radiation of copper (1.54 Å), passes through a bundle of fibres perpendicularly and is received on a photographic plate set perpendicular to the incident beam, is in general a combination of two types: (1) The concentric Debye-Scherrer rings, and (2) the pattern of Laue spots. When Debye-Scherrer rings are obtained the fibre consists of minute crystallites arranged wholly at random. The cellulose fibres always exhibit this crystalline character and the diffuse diffraction rings characteristic of liquids or amorphous solids appear only in the advanced stages of the dispersion of cellulose into a true solution. The completely random distribution of crystallites or miscelles is approached most closely in artificial fibres which are spun without tension. In the natural fibres and the stronger artificial fibres the Debye-Scherrer rings degenerate to localized intensity maxima arranged with two fold symmetry about the equatorial line of the photograph—the line which is perpendicular to the fibre and to the x-ray beam. This is the characteristic fibre diffraction pattern exhibited by asbestos, drawn or rolled metals, stretched rubber, silk (fibroin) and the cellulose fibres ramie, flax, etc. If the fibre possessed a repeating pattern only in its axial direction the diffracted x-rays would proceed outward from the point in the fibre on which the monochromatic primary beam is incident in a series of cones, with the fibre as axis. Each order of reflection would give two half-cones, one above and one below the equatorial plane. The intersections of the cones with the flat photographic plate give the so-called layer line hyperbolas. But localized maxima appear on these hyperbolas, therefore in the fibre there must be present identity periods at right angles to the fibre axis. When the arrangement of molecules has considerable regularity in planes at right angles as well as along the axis we obtain quite intense spots on the layer line hyperbolas as shown by asbestos,[2a] and.[17] With decreasing regularity in the normal to the fibre directions, the spots become more and more diffuse and spread out along the layer lines.[2a]

Only in simple lattices with few degrees of freedom is the exact determination of the atomic positions possible. The elementary body of cellulose contains 4 glucose residues, $C_6H_{10}O_5$, or glucose anhydrides (*i.e.* 24 carbon 20 oxygen and 40 hydrogen atoms). The hydrogen atoms, because of their small electron content, give an inappreciable x-ray scattering. A direct

determination of the atomic positions from the intensities alone is not possible. It is necessary to draw upon chemical information, and the known rules of spacing in simple lattices, and the rational models built up by the chemist to explain the properties of glucose and cellobiose which can be derived from cellulose. Haworth and his co-workers [18] (see numerous articles in the *J. Chem. Soc.*, London) have very thoroughly worked out the model of cellulose from purely chemical means. The fibrous character of cellulose is preserved in imagined subdivision down to the ultimate molecule. It is built of chain-like molecules which individually are fibrous. The chemical evidence, substantiated by x-ray and physical investigations, leads to the following chain formula of cellulose (Fig. 1): Each link of the chain is a

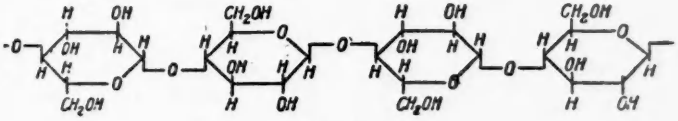
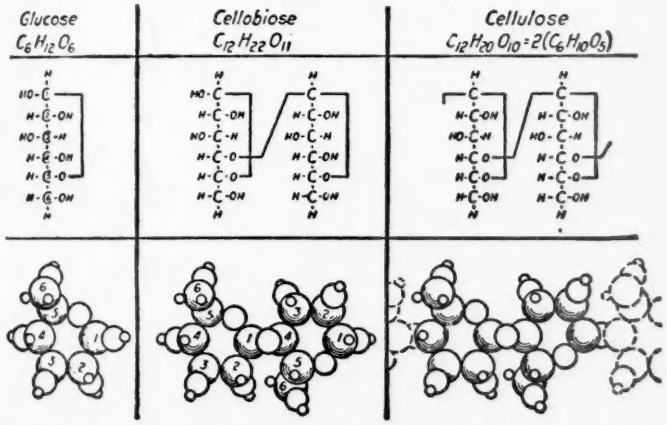


FIG. 1.

β glucose anhydride. The links are held together by oxygen bridges. When the cellulose is broken down into its constituent rings, β glucose results. It can also be broken down in such a way that the rings break off in pairs. The result is cellobiose whose molecule consists of two glucose rings rotated 180° with respect to each other.



EMPIRICAL AND STRUCTURAL FORMULAS AND SPACE MODELS OF GLUCOSE, CELLOBIOSE, CELLULOSE

Space Models according to K. H. Meyer, *Kolloid Zeitschrift*, Vol. LIII (1930), p. 8.

Courtesy American Society for Testing Materials

FIG. 2.

Chemical considerations give certain information about the length of the chain, and are in agreement with the assumption that the chain bends back upon itself to form a ring containing several cellobiose units. X-ray and physical data are, however, in accord with the straight chain model. With the rings extended straight and in the same plane, the cellobiose unit possesses the digonal symmetry of a screw axis. This form agrees with the oxygen valency angles and possesses the required type of symmetry. Certain cellulose derivatives probably possess, instead of the linear chain, a chain in which the planes of adjacent glucose units make an angle with each other.

The identity period 10.3 Å (the length of the double link cellobiose molecule) along the fibre axis can be determined accurately from the spacing of the layer line hyperbolas when monochromatic x-rays are diffracted from a bundle of ramie fibres. 10.3 Å is the length of the b axis of the unit cell of cellulose. The identity period along the fibre axis is the single magnitude which without further assumption can be taken directly from the x-ray diagram. For the other identity periods, that is, the remaining two sides of the unit cell and the angle between them, one must use the equatorial points of the x-ray photograph. But a unique decision as to the exact form of the basis cell cannot be made from the fibre photograph, for all orientations of the crystallites about the axis are possible, so that the reflections from the two planes of the unit cell, which are parallel to the axis, occur with equal intensity. A more highly oriented form of cellulose is necessary. This is found in certain sheet forms of cellulose (B Cellulose) when it is stretched. The micelles orient themselves with their b axes (10.3 Å) in the direction of tension and the 101 and $10\bar{1}$ planes approximately parallel to the film surface. The sides a and c of the unit cell are thus approximately perpendicular to each other.

The arrangement of the atoms in the unit cell (Fig. 3) proposed by Meyer and Mark [2b, 22, 23] has been subjected to test by K. R. Andress [4b]. The atomic positions are given which are in complete agreement with the totality of x-ray observations. The indexing of the planes, the positions and intensities of the spots can be computed and are in exact agreement with experiment. A section through the unit cell is shown in Fig. 4 taken from the paper by Andress.[4c] The chain molecules are normal to the figure. The large circles represent carbon atoms and the smaller ones oxygen atoms. The Roman numerals are the serial numbers of the oxygen atoms counted consecutively around the glucose residue ring. The Arabic numerals are the distances of the oxygen atoms from the plane of the figure.

Size and Shape of the Micelles

The micelle size and shape can be determined in an approximate manner in a powder or fibre x-ray photograph from the half width of the interference pattern lines. Certain assumptions must be made before the computation can be carried out:

1. The crystallites have only one definite size.
2. All crystallites possess the same identity periods.
3. The lattice structure in each crystallite is accurately formed.
4. The heat motions of the atoms cause no appreciable broadening of the lines.

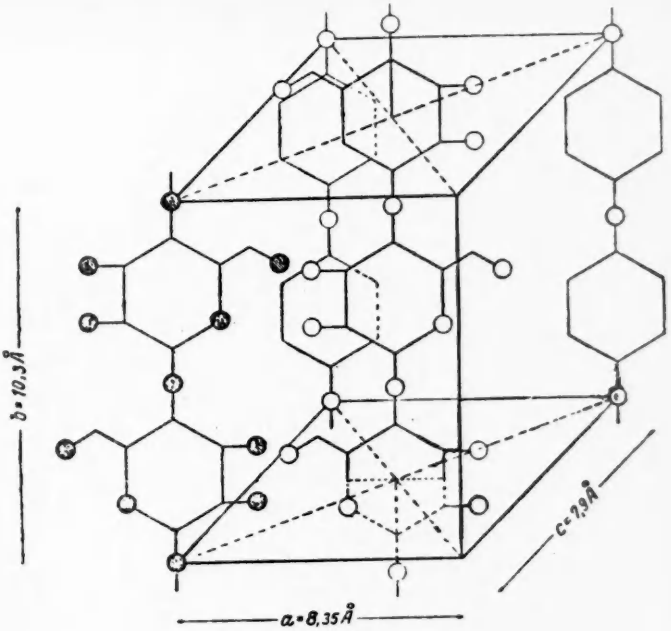

b = 10,3 Å
a = 8,35 Å
c = 7,9 Å

FIG 3.

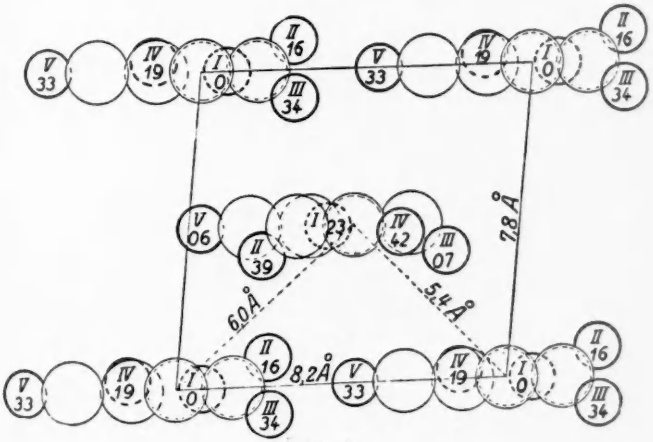

V 33
IV 19
I 0
II 16
III 34
V 06
II 39
I 23
IV 42
III 07
7,8 Å
6,0 Å
5,4 Å
8,2 Å

FIG. 4.

Hengstenberg [24] working with ramie fibres very carefully extracted from the plant and carefully degummed, determined the micelle size of this most nearly perfect specimen. The length along the fibre axis is about 600 Å and perpendicular thereto is 50 Å. The micelles are prisms about ten times longer than wide or thick. By the use of relatively long x-ray wavelengths (Kα of magnesium), G. L. Clark [3] has been able to verify the above values from position measurements of interference pattern spots rather than from line widths.

From the generalized Bragg equations it can be shown that the axes of the unit cell normal to the fibre axis are $a = 8.3$ Å, $c = 7.9$ Å, with an angle of 84° between them. The generally accepted spacial unit which has the fundamental property of cellulose has the following description:

Crystallographic system: monoclinic (three unequal axes, one perpendicular to the plane of the other two which make an angle β with each other).

Unit cell dimensions: $a = 8.3$ Å; $b = 10.3$ Å
(parallel to the fibre axis) $c = 7.9$ Å
$\beta = 84°$

Four $C_6H_{10}O_5$ groups per cell

Space group C_2^2

Mechanical Strength of Cellulose

The most important property of cellulose preparations is their great mechanical strength. In the following table taken from Meyer and Mark's book [2] are listed various common substances with their breaking strengths:

TABLE I

Strengths of different materials in kg/mm²

	kg/mm²		kg/mm²
Cast iron	20 or more	Irish flax	over 100
Hardened spring steel	up to 170	Ordinary Viscose	25
Copper wire	up to 40	Well oriented Viscose	up to 80
Aluminum	up to 10	Ordinary Acetate Silk	18–20
Lead	up to 3	Well oriented Acetate Silk	up to 100
Wood in the fibre direction	8–15	Ordinary rubber	15–20
Silk	35	Well oriented rubber	up to 80
Cotton	28		

The fibres, both natural and artificial, in which the micellar orientation parallel to the fibre axis is best, are exceeded in strength only by the best spring steel. Flax is especially strong. This property which has not been sufficiently emphasized can be rationally explained on the basis of the principal valence chain and micellar structure of cellulose.

An estimation of the maximum value for the strength of a cellulose fibre can be made on the assumption that it is a bundle of principal valence

chains, which extend without break or imperfection through the entire length of the fibre like the strands of a wire rope.

This ideal fibre would then, in effect, be a single crystal made up of the monoclinic unit cells oriented with their long axes (10.3 Å) parallel to the fibre length and the 8.35 Å and 7.9 Å axes normal to the fibre. The section area of a unit cell is $8.35 \times 7.9 \times \sin 84° = 67$ square Ångstroms. Two valence chains contribute to the strength of each unit cell and the section area associated with each is then $67 \div 2$ or about 33 Å^2. For each square millimeter there are $.01 \div 33 \times 10^{-16}$, or 3.0×10^{12}, principal valence chains. If a chain is pulled apart by tension it will naturally break at the oxygen bridge (see Figs. 1 and 2) which is its weakest part. From considerations of heats of dissociation it can be shown that from 70 to 90 kg. cal. per mol. are necessary to break the principal valence bond between carbon and oxygen, or in work units 2.9×10^{12} to 3.8×10^{12} ergs per mol. Dividing these values by Loschmidt's number we have 4.9×10^{-12} to 6.3×10^{-12} ergs work necessary to break a single bond. If the initial separation of the atoms is taken as 1.5 Å, the distance over which the force of the bond opposes the tension will be about 4 Å, for it is known that the attractive force between two atoms falls very rapidly with distance and is negligible for this rough computation at a distance of about 5.5 Å. The average force per bond is therefore from 1.2×10^{-4} to 1.6×10^{-4} dynes. For each mm^2 there are 3.0×10^{12} principal valence chains, which multiplied by the strength of each bond gives from 360 to 480 kg/mm^2, or an average of about 420 kg/mm^2. This is 4.2 times the strength of the strongest and best oriented natural or artificial fibre (see Table I). The large strength has been computed on the basis of a highly idealized structure from which the actual fibres deviate greatly. Instead of one crystal we have many crystallites or micelles each built up by repetitions of the monoclinic unit cells already described. In a well oriented fibre the micelles are laid parallel to each other and are held together by tertiary forces. The molecular chains are held together longitudinally by principal valence forces, and laterally within the micelle by secondary forces of the van der Waal's type which arise in the lateral chemical groups in the glucose rings, principally the OH groups (see Fig. 1). The micelles are formed in nature by building up in some manner to a definite size which is characteristic of the specimen. In ramie the chains are built up to a length of about 500 Å, each containing about 100 glucose residue links. A break then occurs in the uniformity of structure and another micelle begins. The molecular chains add together laterally for distances about 50 Å along the monoclinic axes a and c so that the micelle dimensions are in the ratio 10: 1: 1. Just why the crystallite development is arrested at quite definite dimensions in a given preparation is apparently not clearly understood. This may probably be explained by energy considerations, such as proposed by Zwicky in his secondary and mosaic structure theories.[21, 21a, 21b]

When a native cellulose is broken down in the process of manufacture of an artificial fibre the solvating process begins at the interfaces between micelles, and if conditions are right the micelle size remains essentially unaltered. The resulting fibre, if well oriented, will have a maximum strength. With further dilution, or the action of a stronger reagent, the micelles can be broken into fragments, and in still further dilution the solvating effect of organic reagents can split the micelles into single principal valence chains of glucose residues.[19]

In the various cellulose derivatives different chemical groups are added to the basic six-carbon rings. The lateral cohesive forces between chains thus will be greatly changed, for the chemical groups differ very much in the attractive forces of the van der Waal's type and one can understand why under otherwise comparable circumstances the mechanical properties of cellulose and its derivatives differ so greatly from each other.

The secondary forces holding the chains together laterally within the micelles are weaker than the primary valence forces along the chains. The tertiary forces holding the micelles in position originate in the same chemical groups as the secondary forces, but are considerably weaker because of imperfection of micelle arrangement either accidental or connected with the growth or original formation of the fibre. It is also to be expected, especially with artificial fibres, that the micelles are partly covered with impurities, such as adsorbed water or hemicellulose, which prevent complete development of molecular cohesion. Complete orientation of micelles over the entire fibre section is never fulfilled. Because the forces holding the micelles together are so very small compared with the primary valence forces in the chains, it is to be expected that when a fibre is pulled apart the break occurs, not through the micelles with a severing of the chains, but by slipping of the micelles over each other. Their structure remains intact and they suffer a certain amount of permanent rotation into line with the tension during the plastic yield just before break. The mechanism is more like that of a wool yarn where slipping of the fibres, which individually are very short compared with the length of the yarn, takes place rather than an actual breaking of the fibres.

Meyer and Mark [2c] give an estimate of the strength of a cellulose fibre based on the breaking strength (2–3 kg/mm^2) of cane sugar crystal, which is due essentially to hydroxyl groups or glucosidic oxygen bridges as in cellulose. The break surface of the crystal is a plane, except for a few stepped places, and since it is perpendicular to the axis it has an area about equal to the section area of the specimen. In cellulose the hydroxyl bonds which make up the tertiary cohesive forces are distributed over the surfaces of the prismatic micelles, which intrinsically are very strong and hold together longitudinally and transversely. The break surface in this case will have a toothed or splintered character like the fracture of a wooden bar. The actual break surface will be far greater than the specimen section. To take an ideal case of a perfectly oriented fibre, the micelles will be laid upon each other as are the bricks in a wall. At the break surface each alternate micelle will extend beyond its four nearest neighbors a distance equal to half its length. The break surface will be increased over the specimen section area by half the lateral area of each micelle multiplied by half the number (n) of micelles cut by the cross section. That is, the increased area will be

$$A = nac + (ab + bc)\ n/2$$

The section area $A_o = nac$, where a, b, c are the dimensions of the micelle with (b) parallel to the fibre axis. The actual break surface will be greater than the cross section in the ratio

$$A/A_o = (nac + n(ab + bc/2))/nac$$

But for this rough estimate

$$a = c = 50 \text{ Å and } b = 500 \text{ Å}.$$

Therefore

$$A/A_o = b/a + 1 = 11$$

On the basis of 2–3 kg/mm² strength of the sugar crystal the strength of the fibre will be 20–30 kg/mm². This is only about ⅕ the strength of a well oriented fibre and only 1/20 the 420 kg/mm² strength computed for a perfectly crystalline fibre. Mark and Meyer [2c] obtain an area multiplication of 60 rather than 11. They do not state how it was obtained, but it is a figure which multiplied by the above strength of the sugar crystal gives 150–180 kg/mm², in good agreement with the observed strength of well oriented cellulose. They also do not state the manner in which the 2–3 kg/mm² was obtained for cane sugar. This seems an important omission because the breaking strength of crystals is known to be very much less than the strength computed from the crystalline lattice forces. Joffé [20] has shown that in NaCl crystal the breaking stress is only about 1/400 the calculated value. The surface conditions, and especially surface cracks, decrease the strength enormously. Mechanical strength is a "structure-sensitive" property and depends upon the "secondary structure" or "mosaic structure" [21b] of the real crystal. The strength computed on the assumption of an ideal lattice or primary structure is hundreds of times larger than the observed strength. The 20–30 kg/mm² computed above for cellulose falls within the range (15–35 kg/mm²) reported in this paper for various fibres. The agreement may not be purely accidental if 2–3 kg/mm² is not interpreted as the strength of an ideal, but is the strength of an actual, sugar crystal.

Additional light is thrown on the mechanism of breaking of fibrous materials by the words of W. L. Bragg: [25a] "An initial break at any point in a crystal concentrates the strain upon neighboring regions, which break in their turn. In order to get a body which has a high tensile strength, it must be ensured that when at any point a break does occur, the resulting increase of stress is distributed widely. Tensile strength is, in other words, not so much a question of strength of bonding in the direction of stress as of weakness of bonding at right angles to it. The strength of a sheet of mica or a fibre of asbestos, is due to the very feeble forces with which the sheets or fibres are attached to each other laterally, so that if one fibre gives the additional stress is shared by the rest of the bundle of fibres."

In real fibres, either natural or artificial, the perfect micellar arrangement (*i.e.* long axes parallel) assumed above is not present. Especially in artificial fibre one would expect a great deviation from parallel orientation. The dispersed micelles in the plastic mass before spinning, possess all possible orientations, but, as the filament is extruded into the coagulating bath, a certain amount of orientation takes place on the surface because of friction at the spinnerette orifice and hydrodynamic friction in the bath. Additional orientation can be affected by subjecting the fibres to tension while in the coagulating bath and by the use of certain frictional guide arrangements. The effect of various methods of spinning on the orientation is being studied by x-ray methods at the University of Illinois by G. L. Clark and his co-workers.[3] With random orientation the micelles are in contact in relatively small areas and a small fraction of the lateral chemical groups will be close enough together to exert appreciable cohesive forces between micelles. As a fibre is made more uniform in structure, the strength increases because of increased micelle contact area. The density increases because of closing of intermicelle interstices. In real fibres the micelles are in part covered with impurities, such as hemicellulose or ad-

sorbed water, which satisfy the van der Waal cohesive forces of the lateral chemical groups, especially the OH groups, and decrease the strength thereby because the side-by-side cohesion of the micelles has in part been destroyed. A fibre in which the orientation is perfectly random can be increased about three-fold in strength by a process of orientation, which consists essentially in stretching the fibre slowly in the presence of a swelling medium.

Plastic Deformation

At the present time the mechanism of plastic deformation of the metallic elements is quite well understood from numerous experiments on single crystals. At a certain tension, slipping or gliding occurs along certain atomic planes in the crystal which are not perpendicular to the axis of tension. The magnitude of the yield stress is, however, many times smaller in the real crystal than that computed in the basis of an ideal lattice. The discrepancy is explained by Zwicky,[21] where slipping is facilitated along the π planes of the secondary structure, which is in general a uniform system of crystal planes on which the density of atoms is slightly larger than in the ideal lattice. The secondary or π planes form a space configuration parallel to the primary structure, but are separated by distances several hundred times the separation of the primary planes. Accompanying the gliding there is a rotation of the glide planes into the direction of tension. But the lattice of the whole specimen remains essentially unaltered. After one set of planes has turned a certain extent into the direction of tension, other planes will be in a position to slip, and the stretching process continues. The greater the symmetry of the lattice the greater will be the number of plane-types along which slipping can occur. The highly symmetric cubic metal crystals, such as gold and copper, are very ductile for there are eight possible types of planes of slip. Wires made by drawing show a characteristic fibering parallel to the tension axis. The mechanism of cellulose yield under tension is completely different. While in metals yield occurs through gliding and sometimes "twinning," in cellulose it is the whole crystallites which slide over one another and rotate into parallelism with the tension axis preserving their lattice structure intact. The fibre structure is developed by micellar flowing. "The rational study of this important deformation principle which includes the whole range of plastic masses has not yet been made."[24]

When once the micelles of a cellulose fibre have turned parallel to the fibre axis, plastic yield by more favorable orientation is not to be expected. The yield now takes place by a slipping of the micelles on surfaces which are parallel to the tension, and this leads to a decrease in the total area supporting the tension, and break occurs. It is to be expected that in well oriented fibres the amount of extension would be less than in the unoriented fibres, and such is indeed the case.

Experimental

Since a knowledge of the mechanical strength of fibres is fundamental in the textile industry, it is natural that early in the scientific development of the industry instruments would have been developed for strength measurement on single fibres as well as on fabrics. A discussion of the large num-

ber of different types of instruments, most of which are equipped with ingenious devices to improve the accuracy and reliability of results, would be out of place here. The treatises of Haven [26] and Heermann and Herzog [27] may be consulted for details of practical instruments. The existing machines are entirely too elaborate, and are in general not sufficiently sensitive for the present study. On the basis of operating principle the instruments fall naturally into three classes, depending upon the manner in which the force is applied to the fibre and how it is measured: They are (1) the hydraulic type; (2) the balance type, and (3) the pendulum type. O'Neill's hair tester is an example of the first type. The fibre under test is pulled down vertically by the unsupported weight of a hollow cylinder floating in a vessel of liquid, usually water. As the water is drawn off, the float is held practically stationary by the fibre and the tension increases in proportion to the amount of water drawn off. The force is applied uniformly and without jarring. Baratt's balance is an example of type (2). In it, the lever arm of an accurate analytic balance is used. The fibre is attached to one arm by appropriate means, and an iron bar which can move vertically into a solenoid is attached to the other arm. As the fibre is stretched downwards by a rack and pinion mechanism, the balance index is held at zero by continuously increasing the current through the solenoid. The breaking force is determined from the current vs. force calibration of the solenoid. In type (3) the force of reaction when a pendulum is pulled out of its equilibrium position is used to exert a tension on the fibre. In the Ball's magazine hair tester the fibre is attached to the pendulum bob, and, as the support of the pendulum is moved horizontally the fibre holds the bob near its initial position. The angular deflection of the bob is recorded automatically either by a light stylus or a sparking recorder. Navkal and Sen [28] have made comparative studies of the three typical instruments mentioned above. They find that the instruments do not agree satisfactorily in the determination of the average strength of a large number of fibres taken from the same sample of cotton. The disagreement seemed to be due to inability of the operator to control the applied force accurately, to damage to the fibre in adjustment, to friction and to varying rate of loading.

An adaptation of the simpler and more sensitive devices of Lonsdale [29] and of Polanyi [30] is more applicable here and is easier to build. In Lonsdale's device the fibre is pulled vertically downward and the depression of its upper support causes a twisting of a taut metal ribbon which carries a mirror. The turning mirror deflects a spot of light up and down on a photographic plate. By means of strings and pulleys the plate is attached to the mechanism which pulls the fibre, so that the horizontal motion of the plate is proportional to the fibre extension, provided the movement of the upper end of the fibre is neglected. This can be made small and negligible. The combination of the vertical motion of the light beam with the horizontal motion of the plate results in the tracing of a curve, referred to oblique axes, which can be interpreted to give a true stress-strain curve. This device is especially useful when extensions are to be made rapidly and the return to zero extension is to be investigated. Polanyi,[30] at the Kaiser Wilhelm Institute fur Faserstoffchemie, made an examination of the existing apparatus for fibre testing before beginning an investigation of the plastic deformation of very weak single crystals of the metals. The existing instruments were too insensitive. A new type was devised. It consisted

sorbed water, which satisfy the van der Waal cohesive forces of the lateral chemical groups, especially the OH groups, and decrease the strength thereby because the side-by-side cohesion of the micelles has in part been destroyed. A fibre in which the orientation is perfectly random can be increased about three-fold in strength by a process of orientation, which consists essentially in stretching the fibre slowly in the presence of a swelling medium.

Plastic Deformation

At the present time the mechanism of plastic deformation of the metallic elements is quite well understood from numerous experiments on single crystals. At a certain tension, slipping or gliding occurs along certain atomic planes in the crystal which are not perpendicular to the axis of tension. The magnitude of the yield stress is, however, many times smaller in the real crystal than that computed in the basis of an ideal lattice. The discrepancy is explained by Zwicky,[21] where slipping is facilitated along the π planes of the secondary structure, which is in general a uniform system of crystal planes on which the density of atoms is slightly larger than in the ideal lattice. The secondary or π planes form a space configuration parallel to the primary structure, but are separated by distances several hundred times the separation of the primary planes. Accompanying the gliding there is a rotation of the glide planes into the direction of tension. But the lattice of the whole specimen remains essentially unaltered. After one set of planes has turned a certain extent into the direction of tension, other planes will be in a position to slip, and the stretching process continues. The greater the symmetry of the lattice the greater will be the number of plane-types along which slipping can occur. The highly symmetric cubic metal crystals, such as gold and copper, are very ductile for there are eight possible types of planes of slip. Wires made by drawing show a characteristic fibering parallel to the tension axis. The mechanism of cellulose yield under tension is completely different. While in metals yield occurs through gliding and sometimes "twinning," in cellulose it is the whole crystallites which slide over one another and rotate into parallelism with the tension axis preserving their lattice structure intact. The fibre structure is developed by micellar flowing. "The rational study of this important deformation principle which includes the whole range of plastic masses has not yet been made."[24]

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essentially of a light spring-steel beam supported near its ends on two knife-edges. The specimen was suspended from the center of the beam by means of a yoke and was pulled downward by a calibrated screw which was nicely constructed in order to eliminate backlash. The bending of the beam was measured by the Poggendorf [31] mirror system. Two plane mirrors were set up facing each other on the beam, one over each knife-edge. The image of a scale was reflected once from each mirror before entering a telescope. Karger and Schmid [32] using the device of Polanyi, have made the most thorough investigation of the tensile properties of single fibres so far discovered by the writer.

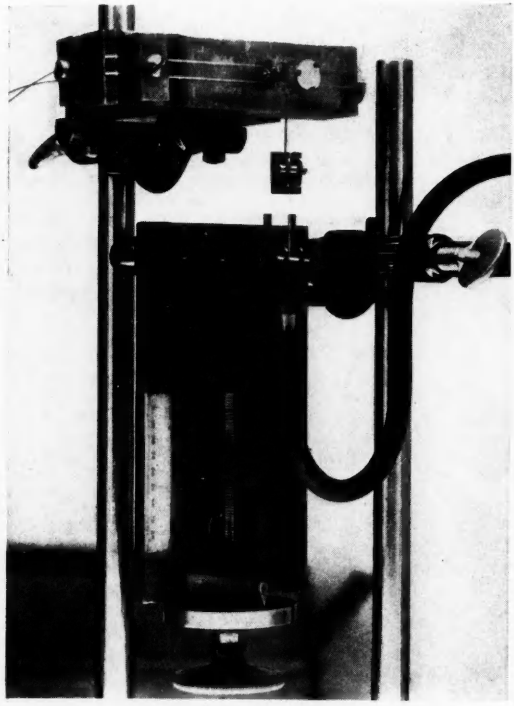

FIG. 5.

Description of the Present Apparatus

In the upper part of Fig. 5 is shown the tension gauge. It consists of a steel block with three frets, across which two 0.013″ music wires are tightly stretched 5 mm. apart, with an initial tension in each wire of 2.34

Kg. The tension can be further increased if desired by screwing down the clamping bar shown on the left. To the centers of the free portions of the wires is fastened, by means of two spring clips, a 1 cm. lever-arm provided with three V-slots, two in a vertical plane which fit over the music wires, and one at outer end of lever which holds the knife-edge and attached upper fibre clamp. If desired the tension in the free portion of each wire can be determined from the pitch of vibration when the lever arm is removed. The arm can be clipped on or off without interfering with the tension or the calibration of the device. It is quite essential for reproducible results that the V-slots be perfectly formed. The shaft which carries the reading mirror is inserted in the lever arm parallel to the wires so that the rotation of the arm can be observed.

Each fibre clamp is made from a plane rectangle of fibre board, on which rests a cylinder of the same material held tightly in contact by means of two slanting wires, so arranged that the fibre tension tends to set the clamps more firmly. This type of clamp can be made very light (the upper one used here weighed only 1.04 g. and no special pains were taken in its construction) and enables one to determine the initial fibre length without ambiguity, because the clamping takes place only along a cylinder element which is in the same horizontal plane as the cylinder axis. A minute spot of white paint in a fine hole drilled in each end of each cylinder accurately marks the ends of the axes. The gauge length of the fibre under test is determined by sighting the telescope of a simple cathetometer on the spots of paint. A strip of plane mirror set up behind the clamps brings the far ends of the clamping cylinders into view so that their separation can also be measured and averaged with the value found from the near ends. The two cylinders can be set parallel with no special care, so that the separation of their ends differ by only a few tenths of a millimeter. With the mirror to scale distance (3.3 m.) used here, and the rather high tension in the music wires, the depression of the lever arm introduces a small error in the extension readings. A correction can however be easily made if desired (see paragraph on Test of Tension Gauge). Because of sensitivity to mechanical vibration the device is arranged on a heavy base-plate which in turn is placed upon sponge rubber mats. Street traffic and building vibrations are damped out sufficiently by this means.

The fibre is pulled downward by a calibrated micrometer screw of ½ mm. pitch. The lower clamp is rigidly attached to the moving slide as shown in Fig. 5. The slide is of conventional design and was borrowed from another instrument. The smallest division on the micrometer head is 0.01 mm.

Humidity Control

The mechanical properties of the textile fibres vary greatly with the amount of water adsorbed on the surface and in the interstices between micelles. The moisture content is related to the humidity of the surrounding air. Wilson and Fuwa [33] show that in textile fibres, both natural and artificial, there is a definite relation between equilibrium moisture content and humidity of the surrounding air as determined by weighing. The moisture content remains constant over the usual range of room temperatures, provided the humidity is kept fixed. Accurate control of humidity during testing of the fibres is quite important. On the academic scale

required here commercial humidity-control devices are quite unnecessary. Wilson [34] gives the details of humidity-control procedure using sulfuric acid solutions when small volumes of air in contact with small samples (50 g.) of textile fibres are to be treated. His method will be used in the present work. A gentle flow of air at a few ounces pressure is forced through three bottles of H_2SO_4 solution in series. The air takes up the amount of water vapor which is in equilibrium with the concentration of acid used. Fifty per cent is used as a standard value of humidity in this study. It is not sufficient simply to expose an open vessel of acid in a closed space with the specimen. By convection and diffusion alone the attainment of equilibrium is prohibitively slow. The treated air is led through a hole in the support for the lower clamp and is confined to the region about the fibre by a glass tube (not shown in Fig. 5) and makes its exit through a hole in a split-glass cover attached to the upper end of the tube. The rod supporting the upper clamp moves freely through the hole in the glass cover. The tube and its cover are held in place by soft wax.

Test of Tension Gauge

Because of the large deflection when the very strong ramie fibre was being tested, doubt arose as to the accuracy of the method of correction of the apparent extension for the drop in the upper clamp. It had been assumed that the effective lever-arm length of the tension gauge is the measured distance of 1 cm. from the plane of the wires to the bottom of the V slot. Careful examination proves this not to be exactly true. The effective lever-arm is 1.083 cm. instead of 1.00 cm. The fulcrum lies 0.83 mm. behind the axial plane of the two wires. This, however, is not serious for it amounts only to a second order correction, and it is not necessary that it be applied to the previously recorded data. The fall of the upper clamp, assuming a lever-arm of 1 cm., is 1.52×10^{-2} mm. per cm. mirror scale deflection, while for the actual lever-arm of 1.083 cm. it is 1.642×10^{-2} mm. per cm.

The ideal way to determine the fall of the upper clamp would be to attach an inextensible and perfectly flexible filament between the clamps, but because of the delicacy of the device no material sufficiently flexible, and at the same time strong enough to support the force without stretch, was obtainable. Kinks and bends introduce spurious extensions. Using a strip of paper between the clamps, the relation between mirror-scale deflection and fall of the lower clamp was obtained. The results are plotted in the lower curve of Fig. 6. The lower part of the curve, which tails off toward the origin, is caused by the straightening out of the unavoidable bend in the paper. The upper part is straight but includes a small unknown stretch of the strip which is proportional to the force. The apparent lever-arm, computed on the assumption of inextensibility of the paper, came out 1.17 cm.; 17% greater than the previously used 1 cm. value. To check this, a micrometer microscope was set up to measure the drop of the lever-arm directly. Because the bottom of the V-slot, in which the knife-edge of the upper clamp rests, was obscured by the clamp-support, the microscope hair was set on the end of the lever 2.22 mm. from the knife-edge. The fall of the end of the lever when weights were added to the upper clamp is plotted in the upper curve of Fig. 6. The plot is a straight line over the whole range of 35 cm. on the mirror scale. The points scatter some-

what because the microscope could not be set closer than 0.01 mm. The precision is sufficient, however, for the determination of a quantity which enters only as a correction. The effective lever-arm length comes out to be 1.083 cm. (= R), taking into account the distance 2.22 mm. from the knife-edge to the end of the lever.

The apparent value of R from the paper strip experiment was 1.17 cm., and the difference 0.087 cm. multiplied by the sine of the angle of the lever

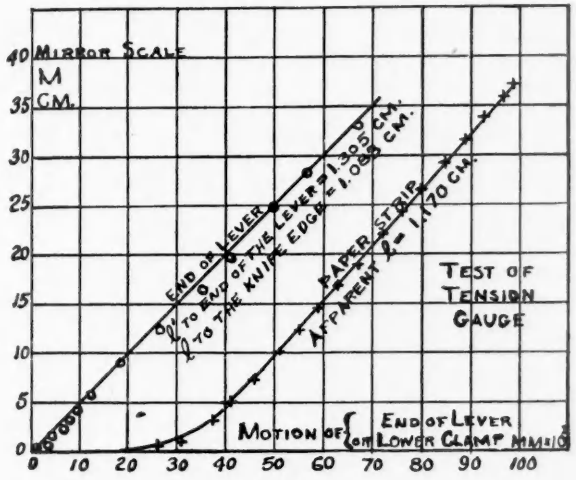

FIG. 6.

deflection gives the stretch of the paper, which was 0.01 cm. for the maximum force (22.8 g.) used.

The correction to be subtracted from the fall of the lower clamp to get the net extension of the fibre under test is therefore

$$d = \frac{R}{2L} D$$

$$= \frac{1.083}{2 \times 330} D$$

$$= 1.641 \times 10^{-2} \text{ mm. per cm. of mirror scale deflection.}$$

L = mirror scale distance.

The value of d used previously was 1.52×10^{-2} mm./cm.

Calibration of Tension Gauge

Immediately after the data for each stress-strain curve had been obtained the tension gauge was calibrated. A light paper pan was hung on the upper clamp by means of a paper tab. As a set of 0.5 gram weights

were added, one at a time, to the pan, the deflection of the mirror was recorded. The load in grams plotted against cm. scale reading is reproduced in Fig. 7. No point deviates from a straight line by an amount greater

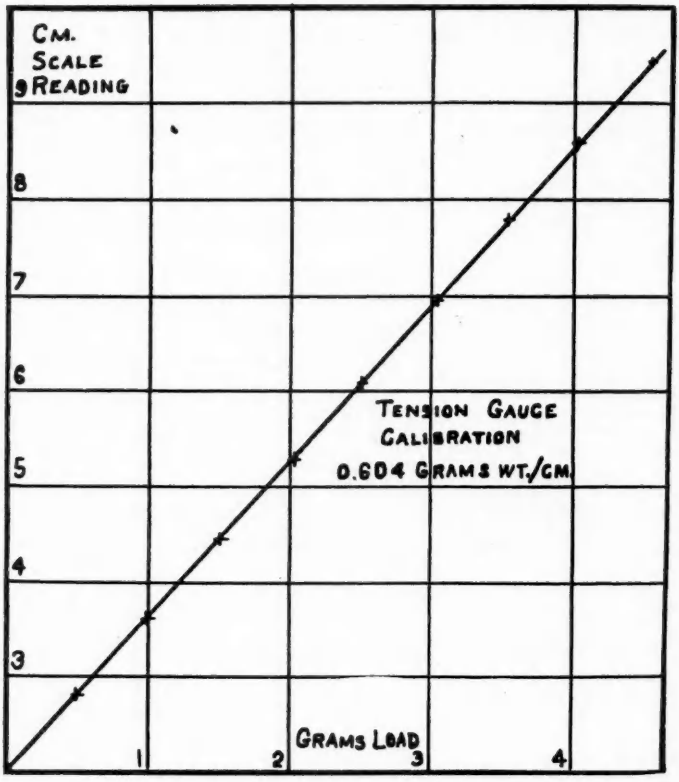

FIG. 7.

than the error of reading the scale, which is probably 0.3 mm. and is equivalent to 18 mg., or 0.4% full scale deflection for, say, the Celanese specimen of Fig. 9. There is no sign of slipping at the wires and the deflection comes back to zero without hysteresis. No friction is present in the device. This will be a very great advantage when the contraction of the fibres is investigated as the tension is released before breaking occurs. One centimeter deflection with a mirror-scale distance of 330 cm. is obtained with a load of 0.604 g.

Section Area Measurement

A Spencer microscope and a camera lucida are used for tracing the section outlines. The over-all magnification is × 900 and was determined by the use of a stage-micrometer graduated in 0.01 millimeters. Free-hand sectioning was not accurate enough for this magnification. A simple equivalent of a microtome was devised. The rather thick (appx 1 mm.) candle-sections were attached to the microscope slide by gentle heat, five or six to a slide. The tops were of course far from plane and were not parallel to the surface of the slide. A set of small, accurately-turned brass rings, ranging in thickness from 0.025″ to 0.055″, were prepared just large enough to fit loosely over a paraffine disc. With some skill, a sharp safety razor blade and a little luck, good plane surfaces parallel to the surface of the slide can be cut, using the surface of the ring as a guide for the blade. After the sections were dyed the outlines were traced on millimeter coordinate paper. The area was determined by counting squares.

The measurement of area is not satisfactory. The individual section area measurements are listed in Table 2. For a given fibre the values dis-

TABLE 2

List of Section Areas

Fibre	Celanese			Bemberg	Viscose	Nitro	Silk	Wool	Cotton	Ramie
Fig. No	8	9	10	11	12	13	14	15	16	17
Image size in mm²	—	394	275	94	211	307	108	650	98	685
		364	250	97	200	310	95	473	107	854
			246	97	219	342	132	590	83	757
			253	102	233	319	111			536
			250		227	330				720
			251		187	383				
					218					
Ave.	—	379	254	97.5	213.4	331.8	112	571	96	713
Section area mm² × 10⁴	—	4.34	3.14	1.20	2.64	4.10	1.38	7.05	1.19	8.08
% deviation from ave	—	9	10	8	21	22	33	31	44	45

agree among themselves by amounts ranging from about 9% of the average in the case of Celanese, to 45% in the case of ramie. Better agreement can probably be obtained by several experimental improvements. The precision of reproduction of section outline, which in the cases studied were at times quite indistinct, can be improved by more elaborate mounting and section-cutting methods. A mounting system whereby the fibre is completely desiccated would eliminate the errors due to lateral swelling of the fibres because of non-homogeneous moisture absorption. Lateral swelling in most fibres, because of moisture absorption, is quite marked. In the case of fine fibres like cotton, greater resolving power in the microscope would help.

Stress-Strain Curves

Stress-strain curves for Celanese single fibres (at three different humidities) are given in Figs. 8, 9, 10. The specimen of Fig. 8 was tested without any consistent procedure with regard to the attainment of internal stress equilibrium. As soon as convenient after the application of stress the tension gauge was read. In the next case, Fig. 9, another fibre from the same spool was tested, but this time a half-minute elapsed between the force

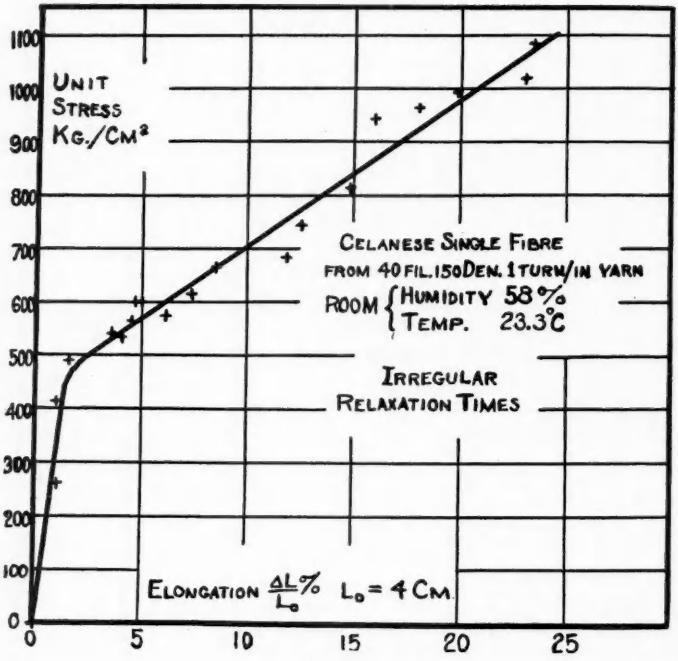

FIG. 8.

application and the tension reading. The points fall on a much smoother curve. A "relaxation time" of a half-minute, therefore, seems to be adequate for sensible attainment of internal stress equilibrium. At least, the equilibrium seems to be uniform. The half-minute probably allows the heat due to stretching to be dissipated. The determination of cross-section area was omitted in the case of the first Celanese fibre. The section area of the second fibre (Fig. 9) was, however, used in reducing the data for Fig. 8 to unit stress values, for the section area in a given spool should not vary greatly. The curves are similar to the stress-strain curves for ordinary metals. There is an initial essentially steep portion from which an elastic

modulus can be determined, followed by a somewhat curved part of lower slope extending to the ultimate where the curve tends to flatten. There is no clear indication of a yield point. One may possibly appear with more refined procedure.

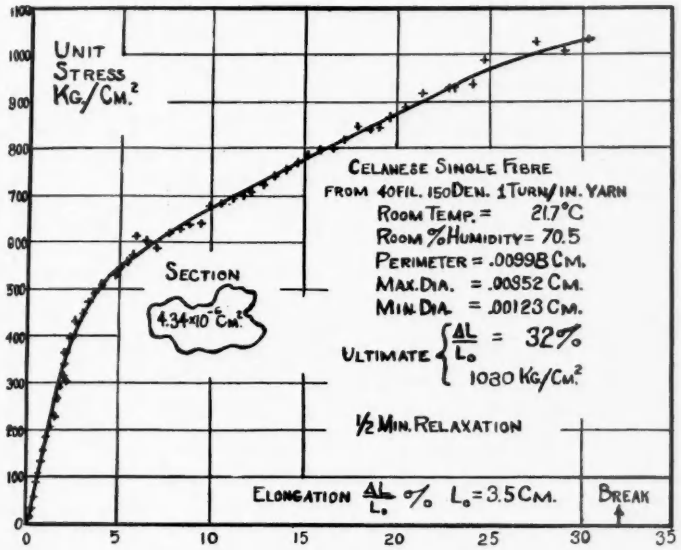

FIG. 9.

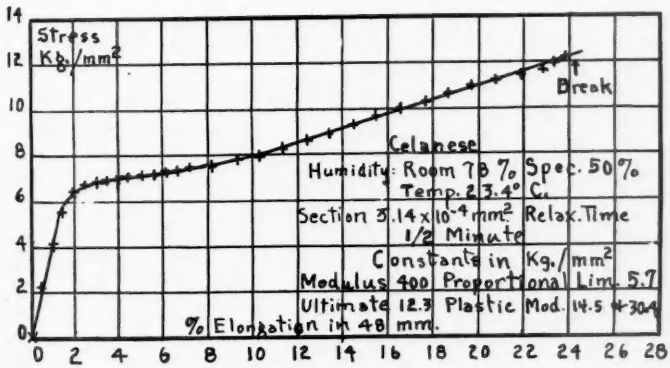

FIG. 10.

The first two Celanese specimens, Figs. 8 and 9, were tested in the open air of the room. The curve of higher humidity (70.5%, Fig. 9) exhibits throughout smaller stresses than does the curve at 58%.

Another specimen of Celanese was tested after the humidity control apparatus had been set up to operate at 50% humidity, the value chosen as standard for this first set of stress-strain curves. The points lie on a much smoother curve than in the case of fibres tested in the open air of the room. It had been discovered that when a fibre is under stress the state of stress responds surprisingly quickly to changes in water vapor pressure of the surrounding air. The greater scattering of points of Figs. 8 and 9 can probably be ascribed to rapid fluctuations in moisture adsorption on the fibre because of connection currents.

A Bemberg cuprammonium rayon stress-strain curve is shown in Fig. 11. Note the similarity between this curve and that of Celanese (Fig. 10), except that the elongation in the latter is twice that of the cuprammonium. An especially well defined modulus of 930 kg/mm² can be determined.

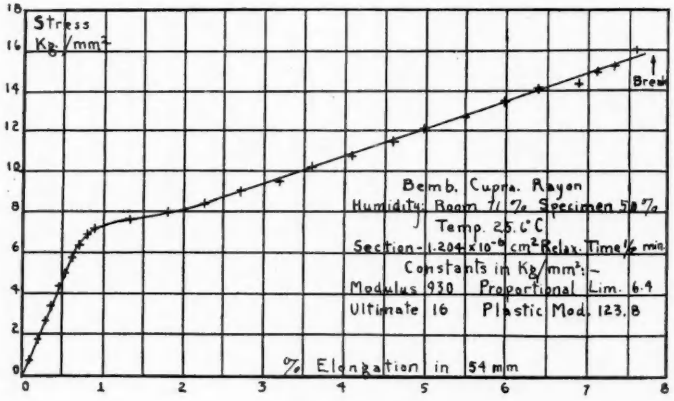

FIG. 11.

Tubize Chatillon viscose yields the curve of Fig. 12. The modulus is not as well defined as in the cuprammonium rayon. There appears to be an indication of yield. The range of the plastic region is quite great. This type of rayon exhibits a very irregular section outline.

In Tubize Chatillon nitro-cellulose rayon (Fig. 13) the half-minute relaxation period seems to be insufficient for the attainment of internal equilibrium. The initial or "modulus" part of the curve is quite straight, but the "plastic" part is quite irregular. The discontinuities at A, B, C coincide with the places where the arbitrary elongation interval was increased.

In silk the yellow sericin, or gum which cements the double filament of raw silk together, was removed by boiling in soap solution. After a single filament selected for tensile test had dried for several hours, part of it was mounted for section measurement and the 5 cm. adjacent thereto was

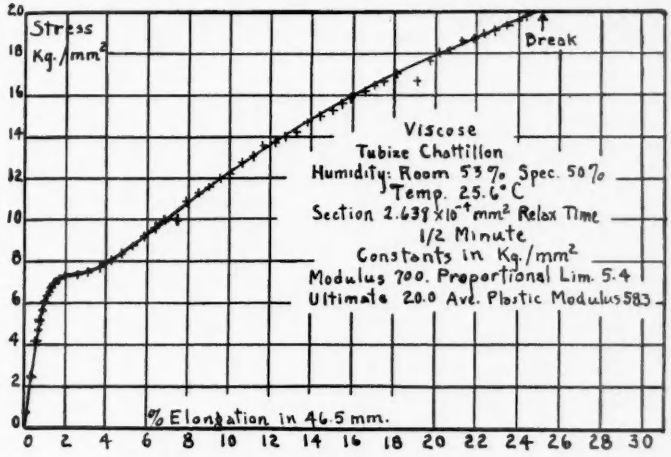

FIG. 12.

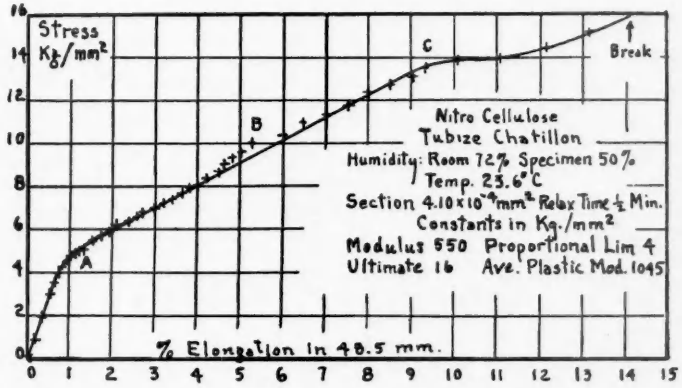

FIG. 13.

mounted in the strain-gauge. Silk does not exhibit the initial straight line stress-strain curve from which a modulus can be determined. The relaxation time of a half-minute is apparently too small. Increases in the stress increment cause changes in the slope (points A and C) much as in the case of nitro-cellulose rayon. The ultimate strength of silk is much greater than that of any of the artificial fibres so far tested. Tubize Chatillon viscose exhibits an ultimate of 20 kg/mm², while for silk it is about 32 kg/mm² with a maximum strength of fibre of 4.47 g.

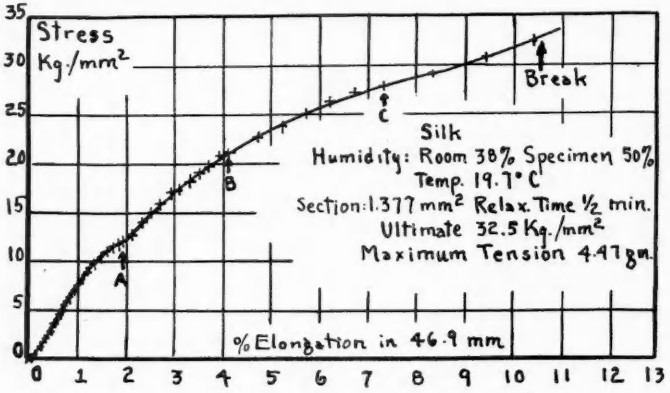

FIG. 14.

The specimen of merino wool tested had a section 7.05×10^{-4} mm², about five times as large as silk. The initial portion of the stress-strain curve (Fig. 15) has a small slope. As in the case of cotton (Fig. 16) this is at least partly due to the straightening out of the very many kinks. Note that in the case of the artificial fibres, which can be obtained free from kinks, that there is no initial flat portion on the curves. The curva-

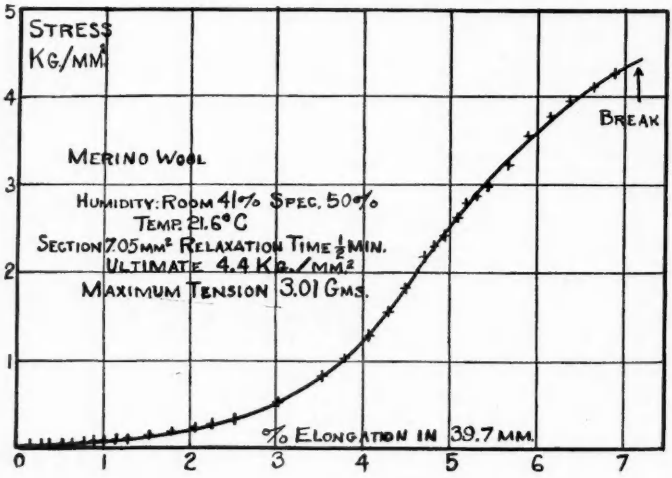

FIG. 15.

ture of the stress-strain graph, as in the case of silk, is continuous, except where artificially changed. There is no evidence of a straight portion obeying Hooke's Law. The ultimate stress (4.4 kg/mm^2) is the lowest so far observed. The maximum load supported by the fibre was 3.01 g.

The fundamental difference in mechanical properties between the animal fibres, wool and silk, and the artificial fibres (regenerated cellulose or its derivatives) is well illustrated by the curves.

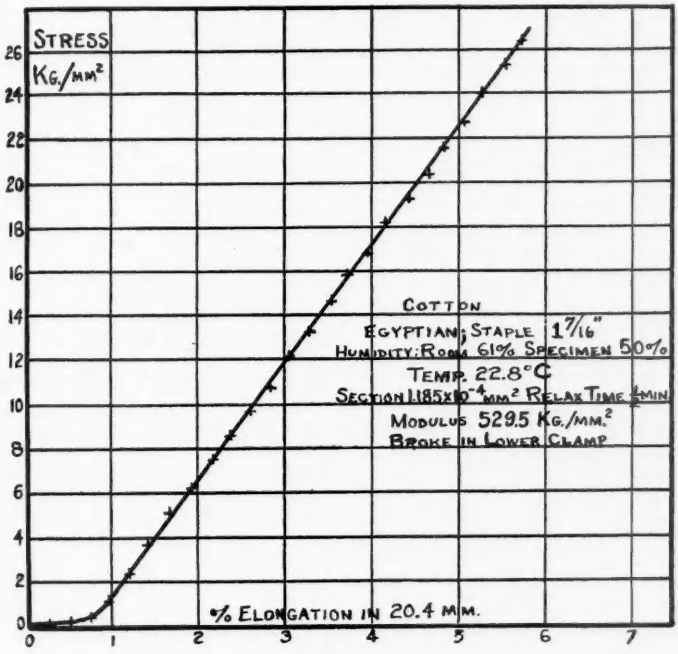

FIG. 16.

Egyptian cotton (1 1/16" staple), exhibits a remarkable stress-strain curve. The plot (Fig. 16) is linear for its entire course. Unfortunately, the lower clamp was pressed down on the fibre so hard as to injure it. Consequently it broke in the lower clamp before the ultimate tension was reached. The bend at the low stress values is not part of the true stress-strain curve, but represents the deflection of the tension gauge as the kinks are removed. The fibre suffers an apparent extension of about 0.8% before the kinks are straightened out. Thereafter the stress is strictly proportional to the per cent elongation.

Because of short length and small section area (1.185×10^{-4} cm.^{2}), together with considerable kinkiness, single cotton fibres are difficult to

handle, especially since in the present work both section area and tensile properties are determined on the same fibre. The sectioning was done using a length of about 0.5 cm., while about 2 cm. were used for tensile test. Because of the fineness of the cotton fibre and the fact that it possesses a hollow shaft, good resolution of detail of cross-section is necessary if precise area measurements are to be made.

Ramie fibre resembles cotton in shape of section and in the possession of a lumen, but, unlike cotton, fissures frequently branch off from the central canal. This is probably due to the low strength in a transverse direction in a fibre in which the micelles are so well oriented. The section area (8.8×10^{-4} cm.^{2}) is about 7.5 times that of cotton, which, combined with its great specific strength, resulted in a total, or fibre, strength which was well beyond the capacity of the tension gauge (Fig. 17). The maximum tension

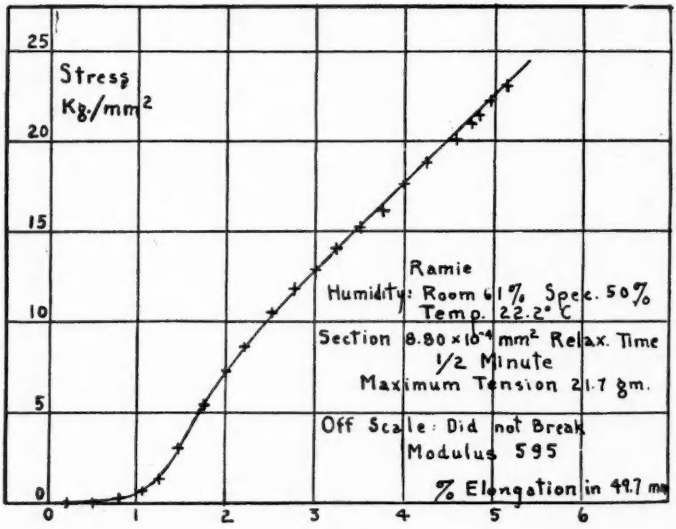

FIG. 17.

(21.7 g.) applied pulled the gauge off scale with a deflection of 33 cm. The experiment on this fibre will be repeated with a different tension gauge calibration so that the course of the stress-strain curve can be followed to the ultimate.

The curve exhibits the flat region as in the case of cotton at low stresses, which represents the removal of kinks and bends. Immediately thereafter there is a region of abnormally great slope. The curve finally settles down to a good straight line with a slope which yields a modulus of 4.81 kg/mm^2 compared with 5.30 kg/mm^2 for cotton.

(*To be continued.*)

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A Critical Study of Cotton Manufacturing Processes

The Irregularity of Card Silver, Dawing Silver, Roving and 28s Yarn Made from 1 1/16 Inch Delta Cotton

By R. L. LEE, JR.*

Introduction

EVENNESS of the diameter of cotton yarn is important to a great degree. Satisfactory strength and suitable appearance of fabrics depend upon the uniformity of the yarns from which they are made.

Cotton, the raw material, is very uneven in many ways, such as length, diameter, and strength of fibre. It is the problem of the cotton yarn manufacturer to produce from a matted mass of tangled and irregular fibres an even and strong yarn of specified count. To produce a yarn it is necessary to process the cotton through from eight to twelve machines. Any one or more of these machines may be the cause of more or less unevenness in the diameter of the strands produced.

Unevenness may be divided into two classes or types: (1) the unevenness or irregularities within short distances in a yarn; (2) the differences in diameter among the strands in a mass being used to produce a fabric.

In attempting to reduce the irregularities among the different strands in manufacturing yarn, the principle of doubling is employed. Doubling is the feeding of more than one strand of material to produce a single strand. That the principle of doubling reduces irregularities within short distances in the product of a machine is hard to visualize, but such has been expressed as the purpose of doubling by some writers.[1]

When one considers the cotton and the many machines with their many parts and purposes, it is remarkable that the product of the cotton yarn manufacturing process is as uniform as it appears to be. Yet, one often wonders to what extent the machines are responsible for irregularity and whether doubling accomplishes its purpose. To attempt to find where and to what extent irregularity is produced is the main purpose of this study. Underlying such a purpose is the hope that the results may be a guide to process improvement and lead to better yarns.

That the study of evenness, or irregularity, is important has been stated by A. J. Turner,[2] W. Lawrence Balls,[3] the Cotton Research Company,[4]

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William King,[5] and others.[6] In most of the few reports of tests on the measurement of the irregularity of cotton strands, the details of the measurement are lacking. In most cases the weights of short lengths of the strands have been used. Instances were found of the use of lengths ranging from six inches up to the customary lengths used in size determination in daily practice in cotton mills. In some cases an indicating instrument has been used, either mechanical or photographic. Among the recent developments is a silver evenness tester which indicates on a chart the irregularities in thickness of the silver.[7] It is also recommended for use with slubber roving. This instrument was developed from a model made by Mr. E. D. Walen. Whether or not it yields results remains to be seen, but the fact that it has been developed emphasizes the thought being given to the study of irregularity.

Conclusions

THE following conclusions are based on the irregularity of the weights of six-inch lengths of the product of the machine. They are also drawn on the hypothesis of as nearly correct mechanical conditions as possible:

Card sliver is very variable.

Through the first process of drawing the irregularity of the sliver decreases greatly.

Through the second process of drawing the irregularity of the sliver remains unchanged to any significant extent.

Through the slubber the irregularity increases markedly.

Through the other roving frames no significant change is produced in the irregularity.

Through the spinning frame the irregularity increases appreciably.

The results did not indicate positively whether there was a marked superiority in uniformity of the regular draft yarn over the long-draft yarn with its fewer doublings, or vice versa.

The overall change in irregularity from card sliver to finished yarn shows an appreciable increase.

A close study of the card, slubber, and spinning frame should be made to determine the specific causes of the increases in irregularity through these machines.

Similar studies on other cotton and other yarn counts should be made.

Development of Methods

In the preparation for this study it was necessary to attempt to find solutions to many problems before a suitable procedure could be set up. Since very few instances were found of similar or related studies, the procedure has to be established by the trial-and-error method in several cases. Therefore, preliminary studies were conducted with the following objectives:

Measurement of the irregularity,
Analysis of the data secured.

In studying physical methods of measuring the irregularity the following were considered:

Length of specimen,
Selection of specimens (sampling).

In studying methods of analyzing the data for irregularity the following were considered:

Statistical measures of variation,
Significant differences,
Number of specimens for a representative sample.

Eight preliminary tests were carried out. Various lots of cotton in the forms of card sliver or drawing sliver were put through one or more of the manufacturing processes and studied for irregularity. The drawing, the slubber, the intermediate roving, the fine roving, and the spinning frames were used.

Length of Specimen

The weight of some short length was thought to be the best indicator of irregularity suitable for this study since no instrument, nor the equipment with which to build or experiment with such an instrument, was available for measuring the irregularity directly. In several previous investigations[2, 4] the weight of some length of material had been used. Six-inch, 18-inch, and 36-inch lengths were tried. Specimens of the desired length were obtained by drawing the material into a folding templet, and cutting the ends flush with the ends of the templet with scissors. The tension on the material as it was drawn into the templet was approximately the same as it would have been had the material been fed to the next machine in yarn manufacturing. It was found that specimens of 6-inch length cut by this means did not vary more than 1/16 in. which introduced an error of not more than 1.04%. The results from the statistical analyses of the weights of the various lengths led to the selection of specimens of 6-inch length as satisfactory for the study of irregularity. Shorter lengths were not used due to the lack of the necessary precise and delicate equipment for cutting and weighing.

Selection of Specimens

Three methods of specimen selection were tried: spot sampling, random sampling, and stratified sampling. Spot sampling is the taking of the specimens from one section of the mass. Random sampling is the taking

of the specimens at scattered places selected by chance only. Stratified sampling is the taking of the specimens by a combination of spot and random sampling. Statistical measures of variation, to be mentioned later, are based on random sampling, but apply to stratified sampling also.[8]

Of the three methods of selecting specimens, the spot method was the easiest and quickest to perform; the random method was the most difficult and time-consuming. When one considered the form of the material to be sampled, especially the probability of adding to its irregularity with much handling, the stratified method of sampling seemed to be preferable. It retains enough randomness to fit the criteria for statistical measures, and also retains some of the ease of spot sampling. Ezekiel writes that when the mass of the material is not uniform throughout, a stratified sample tends to be more reliable than a random sample.[8] In no case in the preliminary experiments was there a significant difference between the coefficients of variation produced from different methods of sampling.

Due to the particular nature of the cotton yarn manufacturing machines and to the difficulty of handling their loosely twisted products, it was impracticable to use the same specimen of the material for the measurement of the irregularity before and after processing the material. As a result the question arose whether or not there should be a place relationship between the samples taken before the material was processed and the samples taken after the material was acted upon by the machine.

Experience with preliminary tests showed that there was no significant difference between results when no place relationship existed between the before- and the after-processing specimens and when a place relationship between the two did exist. Also such a procedure was not practical due to the time and care necessary to maintain such a relation.

Statistical Measures of Variation

After a careful study was made of common and applicable methods of handling and analyzing quantitative data in reports of slightly similar studies and in texts by eminent statisticians, the frequency method was selected as a satisfactory analytical procedure.[9]

Of the several statistical measures applicable to the study of variation, the following were selected as best suited to the data to give the information desired: *Mean, Standard Deviation, Coefficient of Variation,* and their respective *Standard Errors.*

The formulas for these measures and an application of their use follow: [10]

Mean

$$M = A + c$$

where

$$A = \text{an assumed mean}$$

$$c = \frac{\Sigma(f \cdot d)}{N}$$

expressed in class interval units, and is the summation of the products of the frequency: (f) times the deviation (d) of their respective class divided by the total number of specimens (N) in the sample. When c is multiplied

TABLE 1

Calculations for the variation in the weights of six-inch lengths of card sliver arranged as a frequency distribution using 0.01 gram as a class interval.

Class Interval Mid-point Grams	Frequency (f)	Deviation Steps (d)	f · d		f(d)²
0.56	1	− 8	− 8		64
.57	1	− 7	− 7		49
.58	1	− 6	− 6		36
.59	6	− 5	− 30		150
.60	7	− 4	− 28		112
.61	1	− 3	− 3		9
.62	4	− 2	− 8		16
.63	20	− 1	− 20	− 110	20
.64	28	0			0
.65	41	+ 1	+ 41		41
.66	30	+ 2	+ 60		120
.67	36	+ 3	+ 108		324
.68	11	+ 4	+ 44		176
.69	14	+ 5	+ 70		350
.70	8	+ 6	+ 48		288
.71	3	+ 7	+ 21		147
.72	4	+ 8	+ 32	+ 424	256
Totals	216			+ 314	2158

by the class interval value it represents the difference between the assumed mean (A) and the true mean (M).

$$A = 0.64$$

$$c = \frac{+314}{216} = +1.45 \text{ class intervals}$$

or $+ 1.45 \times .01$ gram.

Therefore

$$M = 0.6400 + .0145 = 0.6545 \text{ gram}$$

Standard deviation

$$\sigma = \sqrt{\frac{\Sigma f(d)^2}{N} - c^2}$$

expressed in class interval units.

$$\sigma = \sqrt{\frac{2158}{216} - (1.45)^2} = 2.81 \times .01 = .0281 \text{ gram.}$$

Standard error of the mean

$$\sigma_M = \frac{\sigma}{\sqrt{N-1}}$$

$$= \frac{.0281}{\sqrt{215}} = \frac{.0281}{14.66} = \pm .0019 \text{ gm.}$$

Standard error of the Standard deviation

$$(\sigma_\sigma) = \frac{\sigma}{\sqrt{2(N-1)}}$$

$$= \frac{.0281}{\sqrt{430}} = \frac{.0281}{20.73} = \pm .0014 \text{ gm.}$$

Coefficient of variation

$$V = \frac{100\sigma}{M}$$

$$= \frac{(100)(.0281)}{0.6545} = 4.29\%$$

Standard error of the coefficient of variation

$$\sigma_V = \frac{V\sqrt{1 + 2(V/100)^2}}{\sqrt{2(N-1)}}$$

$$= \frac{4.29\sqrt{1 + 2(.0429)^2}}{\sqrt{430}}$$

$$= \frac{4.298}{20.73} = \pm 0.21\%.$$

Hence

$$M = 0.6545 \pm .0019 \text{ gm.}$$

$$\sigma = .0281 \pm .0014 \text{ gm.}$$

$$V = 4.29 \pm 0.21\%.$$

Significant Differences

The coefficient of variation was found to be the measure best suited to show relative variation. In making comparisons differences in coefficients of variation were found. The question immediately arose as to whether or not the differences were significant.

The standard error is a measure of the reliability of a value and also the measure of the reliability of the difference between values.[11, 12] The standard error of the difference between two measures is equal to the square root of the sum of the squares of the standard errors of the measures.

Stated to fit the measure of variation in this study, the formula [13] is

$$\sigma_{(V_1-V_2)} = \sqrt{(\sigma_{V_1})^2 + (\sigma 6_{V_2})^2}$$

An illustration of the use of this formula applied to results from a preliminary test is as follows:

Card Sliver Coefficient of Variation	$4.29 \pm .21$
Drawing Sliver Coefficient of Variation	$2.17 \pm .11$
Difference	2.12

The standard error of the difference is

$$\sqrt{(.21)^2 + (.11)^2} = \pm .24$$

The difference (2.12) is 8.8 times its standard error (0.24). Is the difference reliable or significant? Ezekiel [14] writes:

> In most statistical work, three times the standard error is taken as the greatest extent to which a given result is likely to be wrong. Even though there is one chance in 370 of being further off than this with samples of 30 or more, or one chance in 67, with samples of 10, most scientists are willing to take the chance that their sample is not that exceptional case. For exceedingly important work, or when absolute accuracy of comparison is essential, even four times the standard error might be used; but for the general run of statistical problems, and with fair-sized samples, it would seem safe to regard three times the standard error as about the largest extent to which conclusions might be out *solely because of the chances of getting* an *unusual sample* in random sampling.

For 8.8 times the standard error the chances are several thousand to one that the difference is due to some factor other than sampling.

Considering the large number of specimens in a sample, the careful method of sample selection and weighing, statistical principles, and odds, differences of three and more times the standard error were considered significant in this study.

Number of Specimens for a Representative Sample

The use of the previously mentioned formulas is based upon the selection of a representative sample from the mass of the material. Nothing had been said so far as to the number of specimens necessary to make such a sample. The greater the number of specimens used, the nearer the result will approach the true measure. In preliminary studies the question of number of specimens was considered to a great extent. Samples composed of from 36 to 400 specimens were studied. The results showed that the variability of the material being studied should be the guide to some extent.

Card sliver appeared to be so variable that a greater number of specimens was thought to be necessary. For example, out of six samples from the same lot of card sliver, one sample had a coefficient of variation of

1.89% and another, 4.16%. The other four samples had coefficients of variation falling between the two mentioned above. In contrast to the range of the coefficients of variation for the card sliver, the extremes for six samples of drawing sliver from the same lot of material were 2.02% and 2.28% respectively.

The number of observations (specimens) necessary to make a representative sample may be estimated by the use of the standard error formula. By choosing a limit for the error, the formula may be solved for the number of specimens. As the coefficient of variation was the measure of irregularity in this study, the standard error of the coefficient of variation was used in making an estimation. By solving the equation

$$\sqrt{2(N-1)} = \frac{V\sqrt{1+2(V/100)^2}}{\sigma_V}$$

for N, the number of specimens necessary to give any stated value for σ_V, the standard error of the coefficient of variation, may be found.

To illustrate, assume a coefficient of variation of 15%, a figure slightly higher than the maximum (14.77%) found in any of the preliminary tests. Assume a permissible standard error in the coefficient of variation of 5%. Substituting, the equation becomes

$$\sqrt{2(N-1)} = \frac{15\sqrt{1+2(0.15)^2}}{0.75},$$

and N equals 210.

The value for N increases slightly as the value for V increases. With a limit of 5% as the standard error of the coefficient of variation, N would be 202 for a coefficient of variation of 5.65%; 204 for 7.82%; 205 for 10%; 209 for 14%. Actual results showed that in samples where 200 or more specimens were used, the standard error was very close to 5% of the coefficient of variation; in samples of less than 200 specimens, the standard error was greater than 5%.

If a greater precision in the coefficient of variation was required, say 4%, it can be shown in a similar manner that the number of specimens necessary would be approximately 313; for 3%, 558; for 2%, 1256; for 1%, 5000. Based on these facts, a standard error in the coefficient of variation of 5% is one that can be obtained reasonably, even in the worst case, by using 210 specimens. But 240 specimens were selected for use in the Final Test and the Check Test because of the ease of factoring 240 to have the specimens taken equally from the different strands fed (doublings) and equally from the different spots.

Summary of Sampling Method and Analysis of Data

The eight preliminary tests were not related specifically one to another, but were made to develop a procedure for studying the irregularity of the whole yarn-manufacturing process. The resulting decisions on procedure to be used in a final comprehensive study may be summarized as follows:

> The variation to be based upon the weights of six-inch lengths of the various forms of the cotton strands.

A stratified method of sampling to be used; namely, specimens from spots selected at random.
A representative sample to consist of 240 specimens, except for card sliver. Card sliver samples to consist of 480 specimens.
All piecings to be marked to prevent the inclusion in a specimen of an irregular place produced by a piecing.
The six-inch specimens to be cut in a folding templet.
The tension applied upon the strands while being inserted in the templet to be approximately the same that the strand would have in being fed to the next step in the cotton yarn-manufacturing process.
The measure of irregularity to be the coefficient of variation calculated from a frequency distribution of the weights of the specimens in a sample.
A significant difference to be one of at least three times the standard error of the difference.

Final Test and Check Test

The previously described procedure was applied to the study of the variation of the product of each of the machines from the card through the spinning frame used in manufacturing 28s warp yarn. In this case the same stock of cotton was used throughout. Two methods of manufacturing were followed: a regular method including all the usual doublings, and a long-draft method eliminating one process and two doublings. Upon the completion of one test, a check test was performed.

Cotton

The cotton used in this study was secured in the form of picker lap from a large cotton manufacturing plant. The lap was produced from a mixture of six to eight bales of Delta, $1\frac{1}{16}$ inch, middling and strict middling cotton. Before passing through a single process picker, the cotton was cleaned by standard cleaning machines as follows: bale breaker, vertical opener, and two lattice cleaners. In the picker the cotton received the action of three beaters. The cotton was oil treated, 0.1% of oil by weight being sprayed onto the cotton at the last beater. The weight of a yard of the lap was 13 ounces. Lap 1 of the cotton was used for the final test and Lap 2 for the check test.

Organization

The organizations shown in Table 2, based on common manufacturing practices, were used for the regular (common) method and for the long-draft method of manufacturing respectively. The two organizations were the same through the intermediate roving frame. The yarn count of 28s warp yarn was selected because of the suitability of the cotton and the manufacturing equipment.

TABLE 2

Organizations

Machine	Draft	Doubling	Size	Twist*
Regular Method				
Picker			13 Oz.	
Card	109	1	49 Grains	
First Drawing	6	6	49 Grains	
Second Drawing	6	6	49 Grains	
Slubber	4.33	1	.736 Hank	.835
Intermediate	5.00	2	1.83 Hank	1.42
Fine Frame	6.00	2	5.50 Hank	2.51
Spinning	10.18	2	28.00 Yarn	24.8
Long-Draft Method				
Picker			13 Oz.	
Card	109	1	49 Grains	
First Drawing	6	6	49 Grains	
Second Drawing	6	6	49 Grains	
Slubber	4.33	1	.736 Hank	.835
Intermediate	5.00	2	1.83 Hank	1.42
Spinning	15.30	1	28.00 Yarn	24.8

* The twists were calculated from the actual speeds of the machines.

Manufacturing Conditions

Mechanical operating conditions were similar to commercial practice for such yarns and were as nearly correct as it was possible to make them. The settings of the different machines are shown in Table 3; the actual speeds in Table 4.

Humidity conditions were controlled by an automatic regulator adjusted for 53% relative humidity. All of the manufacturing machines were located in one room controlled by the regulator.

In order to eliminate as many variable mechanical conditions as possible, only one delivery was used at each machine. The yarns from the two systems were spun simultaneously on the same spinning frame, for one side of the spinning frame was equipped with the Casablancas long-draft arrangement of the drafting rolls and the other side with the common three-roll arrangement.

Sampling Procedure

The detailed sampling of the product of each of the machines was done as follows:

Card Sliver.—As the card sliver was fed to the first drawing frame, several yards of the sliver were removed at four spots selected at random from each of the six cans of sliver fed. The piecings, necessary where the breaks in the sliver were made, were marked by spraying the piecings with a solution of a spirit-soluble-dye in alcohol and ether. It was not necessary to wait for the dye to dry, as the cotton did not stick to the metallic drafting-rolls.

TABLE 3

Machine Settings

Card	Gauge
Feed plate to lickerin	12
Mote knives (top)	15
Mote knives (bottom)	12
Lickerin to cylinder	7
Back plate to cylinder (top)	29
Back plate to cylinder (bottom)	34
Flats to cylinder (back)	10
Flats to cylinder (middle)	10
Flats to cylinder (front)	9
Front plate to cylinder (top)	29
Front plate to cylinder (bottom)	34
Doffer to cylinder	7
Doffer comb to doffer	12
Lickerin screen (front)	17
Lickerin screen (back)	29
Cylinder screen (back)	29

Machine	Diameter of Rolls—Inches				Setting of Rolls Center to Center Inches		
	First	Second	Third	Fourth	First–Second	Second–Third	Third–Fourth
Drawing							
Metallic rolls							
First	1 3/8	1 1/8	1 1/8	1 1/8	1 5/16	1 1/2	1 11/16
Second	1 3/8	1 1/8	1 1/8	1 1/8	1 5/16	1 1/2	1 11/16
Roving Frames							
Leather rolls							
Slubber	1 1/4	1	1		1 9/32	1 17/32	*
Intermediate	1 1/8	1	1		1 1/4	1 9/16	*
Fine Frame	1 3/32	1	1		1 7/32	1 17/32	*
Spinning							
Leather rolls							
Regular	1	7/8	7/8	(top)	1 3/16	1 9/32	†
				(bottom)	1 1/8	1 9/32	†
Long-Draft	1	—	7/8	(top)	1 17/32	1 9/32	†
	Bite of front rolls to leather cots				5/8		

* The settings between the second and third rolls were as close as the rolls could be set.

† The settings between the second and third rolls were fixed, due to the machine construction.

TABLE 4

Speeds of the machines

Machine	Revolutions a minute
Card	
Cylinder	164
Lickerin	346
Doffer	9.5
First Drawing	
Front roll	251
Calender roll	146
Second Drawing	
Front roll	251
Calender roll	146
Slubber	
Front roll	179.5
Spindle	589
Intermediate	
Front roll	139.5
Spindle	701
Fine Frame	
Front roll	134.5
Spindle	1193
Spinning	
Front roll	117.5
Spindle	9000

From each of the samples of sliver, 20 consecutive six-inch lengths were cut. A folding wooden templet was used to measure the six-inch lengths. The ends of the speciments were trimmed with scissors.

First-Drawing Sliver.—As the first-drawing sliver was fed to the second drawing frame, several yards of sliver were removed at four spots selected at random from each of the six cans of sliver fed. The piecings were marked in the same manner as the card sliver piecings. From each sample of sliver, ten consecutive six-inch lengths were cut.

Second-Drawing Sliver.—As the cans were being filled at the front (delivery) of the second drawing frame, samples consisting of several yards were removed from four spots selected at random from each of the six cans produced. Ten specimens were cut from these samples in the same manner as the first-drawing specimens.

Second-Drawing Sliver Fed to the Slubber.—As the second-drawing sliver was fed to the slubber, samples consisting of several yards were removed from six spots for each of the two bobbins of roving produced. From each of these samples, 20 consecutive six-inch lengths were cut in the same manner as for the other sliver.

Slubber Roving.—As the slubber roving was fed to the intermediate, samples of 20 consecutive six-inch lengths were taken from six spots on each bobbin as it stood in the creel of the intermediate. The piecings were marked as they came through the drafting rolls to the front of the machine.

This was necessary because the wet cotton would stick to the leather drafting rolls.

The latter procedure was repeated for the roving used to make the intermediate roving for the long-draft spinning system.

Intermediate-Roving Fed to the Fine Frame.—As the intermediate-roving was fed to the fine frame, samples of 20 consecutive six-inch lengths were cut from six spots selected at random on each bobbin as it stood in the creel.

Intermediate-Roving Fed to the Long-Draft Spinning.—The intermediate-roving fed to the long-draft spinning was sampled in the same manner as the intermediate-roving fed to the fine frame.

Fine-Frame Roving.—As the fine-frame roving was fed to the regular draft spinning system, samples of 20 consecutive six-inch lengths were cut from six spots selected at random on each of the bobbins fed.

Yarn.—From 12 spots selected at random on the two bobbins of yarn, 20 six-inch lengths were cut. The yarn was first wound by an inspection card-winder onto a board covered with felt. With a six-inch steel templet laid over the yarn, the yarn was cut with a safety razor blade. To prevent the short lengths of yarn from curling and twisting, rubber bands were placed over the strands of yarn before the yarn was cut. Six-inch lengths were cut on each side of the board.

This method of cutting was carried out for both the regular and the long-draft yarns.

Conditioning and Weighing of Specimens

All specimens were conditioned for over four hours in an atmosphere of 65% relative humidity. The humidity was controlled by an automatic regulator. The temperature was not controlled, and ranged from approximately 75° to 85° F.

The specimens were then weighed individually on a chainomatic balance; those of the sliver- and the slubber-roving were weighed to the nearest 0.001 g.; those of the intermediate- and fine-frame rovings and the yarn were weighed to the nearest 0.0001 gm.

Analysis of Data

From the recorded weights of the six-inch specimens for each process a frequency table was prepared. The class intervals used in preparing the frequency distributions were as follows:

Sliver	0.01 gm. or 0.02 gm.
Slubber Roving	0.005 gm.
Intermediate Roving	0.001 gm.
Fine-Frame Roving	0.0005 gm.
Yarn	0.0001 gm.

Examples of the limits of the classes and the mid-points of the classes are as follows:

	Limits Inclusive	Mid-point
Sliver	0.550 to 0.559	0.555
Slubber Roving	0.1275 to 0.1324	0.130
Intermediate Roving	0.0390 to 0.0399	0.0395
Fine-Frame Roving	0.0158 to 0.0162	0.0160
Yarn	0.0030	0.0030

The frequency distributions are shown in Tables 5, 6, and 7 for the final test, and in Tables 9, 10, and 11 for the check test.

TABLE 5

Final Test. Frequency distributions for the weights of six-inch lengths of sliver

Class Interval Mid-point Grams	Card Sliver	First-Drawing Sliver	Second-Drawing Sliver	Second-Drawing Sliver Fed to the Slubber
0.465			1	
.475	3		1	
.485	9	3	2	
.495	18	11	3	2
.505	32	25	3	6
.515	31	41	7	14
.525	48	48	25	21
.535	45	37	31	21
.545	39	38	35	31
.555	38	14	47	40
.565	44	13	27	42
.575	33	9	17	25
.585	24	7	18	15
.595	32	1	14	12
.605	23	3	5	7
.615	18		4	3
.625	12			0
.635	9			1
.645	5			
.655	8			
.665	4			
.675	1			
.685	2			
.695	1			
.705	1			
Total	480	240	240	240

From the frequency distributions, by the method described, the following measures were calculated:

Mean,
Standard Error of the Mean,
Standard Deviation,
Standard Error of the Standard Deviation,
Coefficient of Variation,
Standard Errror of the Coefficient of Variation.

These measures, for each sample, are shown in the summary in Table 8 for the final test, and in Table 12 for the check test.

Significant differences were calculated between coefficients of variation of the material fed to and delivered from each machine. These differences

TABLE 6

Final Test. Frequency distributions for weights of six-inch lengths of slubber and intermediate roving

Slubber Roving			Intermediate Roving		
Class Interval Mid-point Grams	Fed to Intermediate		Class Interval Mid-point Grams	Fed to Fine Frame	Fed to Long-Draft Spinning
	for Regular	for Long-Draft			
0.095	1	1	0.0355		1
.100	1	0	.0365		0
.105	6	7	.0375		0
.110	15	22	.0385		0
.115	22	34	.0395	1	0
.120	41	51	.0405	1	2
.125	44	52	.0415	0	2
.130	34	39	.0425	1	2
.135	35	20	.0435	4	5
.140	13	10	.0445	3	5
.145	14	2	.0455	7	10
.150	11	1	.0465	5	16
.155	2	1	.0475	21	25
.160	0		.0485	17	25
.165	1		.0495	20	18
			.0505	14	32
			.0515	20	20
			.0525	27	28
			.0535	25	22
			.0545	22	9
			.0555	11	6
			.0565	17	5
			.0575	9	4
			.0585	6	1
			.0595	6	2
			.0605	3	
Total	240	240		240	240

are shown in Table 13. A negative difference indicates a greater coefficient of variation after the material was processed through the particular machine than before.

TABLE 7

Final Test. Frequency distributions for the weights of six-inch lengths of fine frame roving and of yarn

Fine-Frame Roving		Yarn		
Class Interval Mid-point Grams	Fed to Regular Spinning	Class Interval Mid-point Grams	Regular Spinning	Long-Draft Spinning
0.0125	1	0.0022		1
.0130	1	.0023		1
.0135	1	.0024	1	0
.0140	6	.0025	1	5
.0145	6	.0026	4	4
.0150	23	.0027	4	16
.0155	28	.0028	28	27
.0160	51	.0029	13	17
.0165	40	.0030	46	34
.0170	25	.0031	34	25
.0175	23	.0032	38	30
.0180	10	.0033	13	14
.0185	12	.0034	29	22
.0190	9	.0035	16	16
.0195	3	.0036	6	13
.0200	1	.0037	4	5
		.0038	3	6
		.0039		3
		.0040		1
Total	240		240	240

TABLE 8

Final Test. Summary of the analyses for the irregularity in the weights of six-inch lengths of the material fed to and delivered from the cotton yarn-manufacturing machines

Line No.	Material	Number of Specimens in Sample	Class Intervals in Grams	Number of Class Intervals	Mean ± S. E. Grams	Standard Deviation ± S. E. Grams	Coefficient of Variation ± S. E. Per Cent
1	Card Sliver	480	0.01	24	0.5584 ±0.0020	0.0436 ±0.0014	7.82±0.25
2	First-Drawing Sliver	240	.01	13	.5320 ± .0016	.0239 ± .0011	4.49± .21
3	Second-Drawing Sliver	240—	.01	16	.5532 ± .0017	.0263 ± .0012	4.76± .22
4	Second-Drawing Sliver Fed to the Slubber	240	.01	15	.5555 ± .0017	.0255 ± .0012	4.59± .21
5	Slubber Roving, Regular Organization	240	.005	15	.1273 ± .0008	.0116 ± .0005	9.12± .42
6	Slubber Roving, Lond-Draft Organization	240	.005	13	.1231 ± .0006	.0091 ± .0004	7.40± .34
7	Intermediate Roving, Regular	240	.001	22	.0519 ± .0003	.0040 ± .0002	7.74± .36
8	Intermediate Roving, Long-Draft	240	.001	25	.0500 ± .0003	.0036 ± .0002	7.40± .34
9	Fine-Frame Roving, Regular	240	.0005	16	.01643± .00008	.00125± .00006	7.61± .35
10	Yarn, Regular	240	.0001	15	.00306± .00002	.00026± .00001	8.50± .39
11	Yarn, Long-Draft	240	.0001	19	.00313± .00002	.00033± .00002	10.54± .49

TABLE 9

Check Test. Frequency distribution for the weights of six-inch lengths of sliver

Class Interval * Mid-point Grams	Card Sliver	Class Interval Mid-point Grams	First-Drawing Sliver	Second-Drawing Sliver	Second-Drawing Sliver Fed to Slubber
0.42	2	0.485			1
.44	2	.495		1	2
.46	4	.505		1	2
.48	3	.515		9	11
.50	18	.525		19	27
.52	21	.535	2	30	25
.54	35	.545	6	36	43
.56	58	.555	21	33	41
.58	80	.565	36	39	39
.60	65	.575	22	30	24
.62	59	.585	32	12	16
.64	43	.595	30	18	6
.66	29	.605	32	7	3
.68	20	.615	18	4	
.70	12	.625	24	1	
.72	11	.635	11		
.74	5	.645	5		
.76	7	.655	0		
.78	1	.665	1		
.80	4				
.82	0				
.84	1				
Total	480		240	240	240

* 0.02 has been used as a class interval for the card sliver because of the great range of the weights of the six-inch lengths.

TABLE 10

Check Test. Frequency distributions for the weights of six-inch lengths of slubber and intermediate roving

Slubber Roving			Intermediate Roving		
Class Interval Mid-point Grams	Fed to Intermediate		Class Interval Mid-point Grams	Fed to Fine Frame	Fed to Long-Draft Spinning
	for Regular Draft	for Long-Draft			
0.100		1	0.0415	1	
.105	4	4	.0425	0	2
.110	6	12	.0435	1	5
.115	23	31	.0445	5	13
.120	48	44	.0455	14	25
.125	47	44	.0465	15	14
.130	55	58	.0475	21	24
.135	31	22	.0485	28	22
.140	14	13	.0495	30	28
.145	7	7	.0505	18	17
.150	5	1	.0515	33	17
.155		3	.0525	16	16
			.0535	21	16
			.0545	14	11
			.0555	8	13
			.0565	7	10
			.0575	3	4
			.0585	3	0
			.0595	1	1
			.0605	1	1
			.0615		1
Total	240	240		240	240

TABLE 11

Check Test. Frequency distributions for the weights of six-inch lengths of fine frame roving and of yarn

Fine-Frame Roving		Yarn		
Class Interval Mid-point Grams	Fed to Regular Spinning	Class Interval Mid-point Grams	Regular Spinning	Long-Draft Spinning
0.0130	7	0.0023	1	
.0135	10	.0024	4	
.0140	19	.0025	10	
.0145	41	.0026	11	
.0150	51	.0027	11	
.0155	42	.0028	19	4
.0160	24	.0029	12	4
.0165	17	.0030	25	14
.0170	16	.0031	9	14
.0175	8	.0032	26	24
.0180	4	.0033	16	17
.0185	0	.0034	16	26
.0190	1	.0035	21	27
		.0036	13	19
		.0037	11	24
		.0038	18	15
		.0039	6	11
		.0040	7	16
		.0041	2	5
		.0042	2	12
		.0043		4
		.0044		3
		.0045		1
		.0046		1
Total	240		240	240

TABLE 12

Check Test. Summary of the analyses for the irregularity in the weights of six-inch lengths of the material fed to and delivered from the cotton yarn-manufacturing machines

Line No.	Material	Number of Specimens in Sample	Class Intervals in Grams	Number of Intervals	Mean ± S. E. Grams	Standard Deviation ± S. E. Grams	Coefficient of Variation ± S. E. Per Cent
1	Card Sliver	480	0.02	22	0.6014 ±0.0029	0.0634 ±0.0020	10.54±0.34
2	First-Drawing Sliver	240	.01	14	.5911 ± .0017	.0261 ± .0012	4.41± .20
3	Second-Drawing Sliver	240	.01	14	.5580 ± .0016	.0245 ± .0012	4.39± .20
4	Second-Drawing Sliver Fed to the Slubber	240	.01	13	.5520 ± .0014	.0220 ± .0010	3.98± .18
5	Slubber Roving, Regular Organization	240	.005	10	.1267 ± .0006	.0090 ± .0004	7.10± .33
6	Slubber Roving, Long-Draft Organization	240	.005	12	.1256 ± .0006	.0095 ± .0004	7.56± .35
7	Intermediate Roving, Regular	240	.001	20	.0505 ± .0002	.0034 ± .0002	6.74± .31
8	Intermediate Roving, Long-Draft	240	.001	20	.0500 ± .0002	.0038 ± .0002	7.60± .35
9	Fine-Frame Roving, Regular	240	.0005	13	.01529± .00007	.00111± .00005	7.26± .33
10	Yarn, Regular	240	.0001	20	.00323± .00003	.00043± .00002	13.31± .62
11	Yarn, Long-Draft	240	.0001	19	.00355± .00002	.00038± .00002	10.70± .49

TABLE 13

Summary of analyses for significant differences in the changes produced in the coefficients of variation of the material through the machines

Machine	Reference Lines in	Difference Between Coefficients	Standard Error	Significance Ratio *
Final Test, Table 8				
First Drawing	1, 2	+ 3.33	0.34	+ 9.8
Second Drawing	2, 3	− 0.27	.30	− 0.9
Slubber	4, 5	− 4.53	.47	− 9.7
Slubber	4, 6	− 2.81	.40	− 7.0
Intermediate	5, 7	+ 1.38	.55	+ 2.5
Intermediate	6, 8	0.00	.48	0.0
Fine Frame	7, 9	+ 0.13	.50	+ 0.2
Spinning, Regular	9, 10	− 0.89	.52	− 1.7
Spinning, Long-Draft	8, 11	− 3.14	.60	− 5.2
Check Test, Table 12				
First Drawing	1, 2	+ 6.13	0.39	+ 15.7
Second Drawing	2, 3	+ 0.02	.28	+ 0.7
Slubber	4, 5	− 3.12	.38	− 8 2
Slubber	4, 6	− 3.58	.39	− 9.2
Intermediate	5, 7	+ 0.36	.47	+ 0.7
Intermediate	6, 8	− 0.04	.49	− 0.1
Fine Frame	7, 9	− 0.52	.47	− 1.1
Spinning, Regular	9, 10	− 6.05	.70	− 8.6
Spinning, Long-Draft	8, 11	− 3.10	.60	− 5.2
Between Long-Draft and Regular-Draft at the Spinning Frame				
Final Test, Table 8	11, 10	+ 2.04	0.63	+ 3.2
Check Test, Table 12	11, 10	− 2.61	.79	− 3.3†
Overall Change Between Card Sliver and Yarn				
Final Test, Table 8				
Regular	1, 10	− 0.68	0.46	− 1.5
Long-Draft	1, 11	− 2.72	.55	− 4.9
Check Test, Table 12				
Regular	1, 10	− 2.77	0.71	− 3.9
Long-Draft	1, 11	− 0.16	.60	− 0.3

* + sign indicates decrease in irregularity.
— sign indicates increase in irregularity.

† The long-draft yarn was the more irregular in the final test, and the regular-draft yarn in the check test.

Discussion

Based on the results of the final test and the check test, and using the coefficient of variation as an indicator of irregularity, the following results by processes were shown:

The first-drawing process improved the uniformity of the sliver considerably.

The second-drawing process did not change the uniformity of the sliver to any noticeable extent.

The slubber increased the irregularity to almost double that of the material fed.

The intermediate did not change the irregularity to any noticeable extent.

The fine-frame did not change the irregularity to any noticeable extent.

The spinning-frame increased the irregularity.

To more easily picture the described changes in irregularity which took place in the various processes, the significance ratios in Table 12 are presented in the following form:

	First Drawing	Second Drawing	Slubber	Intermediate	Fine Frame	Regular Spinning	Long Draft Spinning
Final Test	+ 9.8	− 0.9	− 9.7 − 7.0	+ 2.5 0.0	+ 0.2	− 1.7	− 5.2
Check Test	+ 15.7	+ 0.7	− 8.2 − 9.2	+ 0.7 − 0.1	− 1.1	− 8.6	− 5.2

Only through three machines, the first-drawing frame, the slubber, and the spinning frame were the changes in coefficients of variation great enough to be considered significant; that is, due to something other than the chances of getting an unusual sample. Even then, for the regular method of spinning in the final test the change was not significant; but its trend was in keeping with the change in the check test.

It must be borne in mind that the irregularity in large-scale yarn manufacturing may not agree with the results (irregularity) described here. For instance, it is possible in commercial practice for the product (28s yarn) to be made from sliver from 288 cards, probably from less, but certainly from more than one as was the case in this study. Also, commercial yarn may be made from the product of as many as eight slubber spindles, whereas in this study the yarn is affected by only one slubber spindle.

Two methods of producing the yarn were studied to determine the effect of doublings. For the regular, or common method, the material was doubled 288 times from the card through the spinning. For the long-draft method, the material was doubled 72 times from the card through the spinning. Although the doublings for the long-draft method were one-fourth of those for the regular-draft method, no difference in irregularity proportionate to the

difference in doublings existed between the yarns. No statement can be made as to which method produced the more uniform yarn, for in the final test the regular-method produced the least variable yarn, and in the check test the long-draft method produced the least variable yarn.

A comparison of the check test with the final test showed that the card sliver for the check test was more irregular than that for the final test, so much so, that a larger class interval had to be used in preparing the frequency distributions for the weights of the six-inch lengths of sliver. The cotton used in the two tests came from two laps produced on the same single-process picker, and only a few minutes apart. The laps were converted into card sliver on the same card with the same draft, settings, speeds, and with approximately the same moisture conditions, but several weeks apart. The card was not used for production during the interval. The mean for the weights of six-inch lengths of the card sliver was heavier for the check test than for the final test. Since the card conditions were the same for both the laps, the differences were probably due to differences in the laps produced at the picker.

The difference in weights necessitated a slight change in the drafts at the later processes. The drafts, calculated from the means of the six-inch lengths of the fed and the delivered material at each machine, were as follows:

Machine	Final Test	Check Test
First Drawing	6.30	6.11
Second Drawing	5.78	6.36
Slubber (for Regular)	4.36	4.36
Slubber (for Long-Draft)	4.50	4.40
Intermediate (for Regular)	4.90	5.01
Intermediate (for Long-Draft)	4.93	5.03
Fine Frame (for Regular)	6.32	6.62
Spinning (Regular)	10.75	9.47
Spinning (Long-Draft)	15.98	14.05

The effective draft from the first drawing through the spinning was as follows:

Method	Final Test	Check Test
Regular	182.4	178.4
Long-Draft	186.2	169.4

The total draft to produce the yarn from the card sliver was as follows:

Method	Final Test	Check Test
Regular	52,531	53,626
Long-Draft	12,845	12,197

It may be seen that for the check test (Table 12) the coefficient of variation for the products of the machines from the first drawing through the fine frame were slightly smaller than those for the final test (Table 8) in spite of the fact that the initial material was more variable in the check test. This result is probably due to the evening effect of the first-drawing operation. Although the first-drawing process did not produce the same de-

crease in coefficient of variation in both tests, it is quite apparent that doubling at this operation does markedly smooth out irregularities in the card sliver fed.

Taking the product of the card as a starting basis, no overall improvement in irregularity was shown. The trend was toward increased irregularity. In the final test the increase was from 7.8% to 8.50%, which is an increase of 8.7% when based upon the coefficient of variation for the card sliver. The corresponding value for the long-draft method was 34.3%. In the check test the increase for the regular-draft method was from 10.54% to 13.31%, which is an increase in irregularity of 26.3% when based upon the coefficient of variation for the card sliver. The corresponding value for the long-draft method was 1.52%. The overall changes in irregularity expressed as significance ratios were as follows:

Final Test, Regular method	—1.5
Long-Draft method	—4.9
Check Test, Regular method	—3.9
Long-Draft method	—0.3

In spite of the fact that two out of the four significance ratios are less than three, the trend is toward an increase in irregularity.

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Co-operative Research

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"For the textile industry particularly, with its more than 7000 individual units, co-operative effort is the logical means of providing the fundamental research that is needed to develop the new knowledge that will be the source of new products, and of new uses and new adaptations for old products." From "Survey of Textile Research in the United States, 1931."*

THE two small groups of textile men who started the movement for organized fundamental textile research in this country recognized that it required for its success the co-operation of all branches of the industry. Their first step toward organization was to invite fourteen of the industry's leading national associations to appoint representatives to confer on the subject. That meeting, which was held in Boston April 30, 1930, resulted in the adoption of a resolution authorizing the extending of invitations by an appointed committee to twenty-nine national textile associations, seven textile schools, and eight governmental departments, each of these bodies being asked to appoint a representative who might act upon a preliminary board of directors whose duty it shoulld be to adopt some definite plan of organization of an "American institute for textile research."

Representatives of thirty-four of these bodies accepted the invitation and met in New York City May 23, 1930, and organized with a preliminary board of twenty-four directors representing an equal number of different textile bodies. It was this board, and the officers, executive committee and research committee elected by it, that was responsible for the development of plans that resulted Nov. 6, 1930, in the permanent organization of U. S. Institute for Textile Research, and in its incorporation in December, 1930, under the membership corporation laws of New York state.

Unbiased testimony as to the broad co-operative character of this movement and of the organization resulting therefrom, and also as to the unselfish attitude of its original promoters, is contained in the following excerpt from an editorial in *Textile World* of Aug. 9, 1930:

"This institute is not an organization; it can best be described as an 'idea.' It is not trying to impose a plan upon an industry; it is an attempt to offer to the industry an opportunity to find expression for its own recognition of the need for research. It is not a group of men who wish to direct a research institute; it is a group that wishes to induce the industry to direct its own institute.

* Compiled for The Textile Foundation by U. S. Institute for Textile Research, Inc.

"This absence of self-interest was demonstrated when the Textile Research Council and the American Association of Textile Chemists and Colorists, both with a long background of ardent missionary work in this direction, subordinated their identity, as organizations, and merged their interests in the new Institute. It was demonstrated when the first-named of these two organizations offered its own articles of incorporation to the United States Institute. It was demonstrated when various associations sent either official representatives or unofficial observers to participate in the preliminary organization. It was demonstrated finally when it was announced that the directors and officers, elected in July, would resign at the first annual meeting in November in favor of successors to be elected for the full terms described in the by-laws."

Co-operation of as representative a cross-section of the domestic textile industry as it was possible to bring together at that time was responsible for the organization of U. S. Institute. Its incorporation certificate and its by-laws provide for the maintenance of this policy of co-operation in scientific and economic research for the whole industry. For the full achievement of its objectives, however, that co-operation must be adequately representative of the great domestic textile industry.

(*Continued from page 206.*)

everything that an organization of this kind can provide the industry in its associational and individual capacities.

Several associations have already sought the services of this Institute in the study of specific problems, some directly and some through individuals holding membership in this Institute and in some one of its parent associations. The services of United States Institute for Textile Research, Inc., are available to all national textile associations, whether or not they were among the twenty-two which were responsible for its birth. If, however, a formal offer of its services to an association becomes necessary to encourage the initiation of that inter-industrial co-operation for which it was organized the Institue will assume this to be an obligation.

Abstracts

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwarz, Chairman, Dr. W. E. Emley, Prof. Louis A. Olney and M. W. Weiss.

I. Fibres (Synthetic and Natural) and Fibre Analysis

Cellulose: Hygroscopic Moisture of. XII. Determination of Hygroscopic Moistures of Various Cellulose Products. Sutezo Oguri *J. Soc. Chem. Ind., Japan* 36, Suppl. binding 1933, P. 504–6; *Chem Abs.*, V. 27, P. 2801.

The moisture contents of various samples of cellulose were detd. Their hygroscopic capacity decreased in the following order: Viscose film, cuprosilk, Tomatex, Celotex, esparto pulp, straw pulp and parchment paper, Japanese paper, soda pulp and acetate rayon. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5963.) (W)

Cotton Structure: Theories of. Anon. *Am. Dye. Rpt.*, May 8, 1933, P. 299.

A brief review of a paper by F. T. Pierce published in the *Trans. of the Faraday Soc.* (1930), V. 26, P. 809 and one by Reinhardt Thiessen, *Ind. Eng. Chem.* (1932), V. 24, P. 1032. (See abstract in *Tex. Rsch.*, Dec. 1932, P. 137.) (S)

Deformation Mechanism of Fibrous Substances. I. O. Kratky. *Kolloid-Z.*, 1933, V. 64, P. 213–22; *Chem. Abs.*, V. 24, P. 4679.

Equations, used in the previous article, are derived relating the orientation, calcd. from x-ray diffraction data, and double refraction to stretch, normal and parallel to the films. The ideal model is a highly swollen film consisting of 2 phases, elongated micelles and an intermicellar homogeneous continuum, the system being relatively dil. in micelles. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5608.) (W)

Hydration of Fibres. H. Sobue and M. Nagano. *J. Soc. Chem. Ind., Japan* 36 Suppl. binding 1933, P. 475–82.

Sorption of water consists of the adsorption and diffusion (absorption) of water in the fibre. Theoretical equations for both processes are developed and were found to agree well with exptl. results. Desorption of water by fibre consists of the escape (diffusion to air) and the diffusion of water in the fibre. The theoretical equations were developed and agreed with exptl. results which are presented in graphical form. Fibres studied

were viscose rayon, cuprammonium rayon, raw silk and wool. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5983.) (W)

JUTE LIGNIN: CHEMISTRY OF. II. POTASH FUSION OF LIGNIN. Pulin Behari Sarkar. *J. Indian Chem. Soc.*, 1933, V. 10, P. 263–70; *Chem. Abs.*, 1932, V. 26, P. 602.

Potash fusion of jute lignin (I) yields $(CO_2H)_2$, $PrCO_2H$, protocatechuic acid, pyrocatechol and lignic acid. The formation of these products proves that I is not essentially different from other wood lignins. Delignified jute fibre gives neither aromatic substances nor $PrCO_2H$ when similarly treated. Cross and Bevan's formula (*J. Chem. Soc.*, 1882, V. 41, P. 90) is untenable as it cannot explain the formation of these products. I is attacked at a comparatively lower temp. than wood lignins, the best yield being obtained at 220–30° for 1 hr. Lignic acid is the precursor of protocatechuic acid and thus of catechol. The so-called synthetic lignin is different from native lignin in jute. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5309.) (W)

SILK: CHANGE IN PHYSICAL AND CHEMICAL CHARACTER OF, CAUSED BY WEAKENING OF LARVA. G. Colombo. *Bull. uff. R. Staz. sperim. Seta*, 1932, V. 2, P. 22–26 (through *Chem. Zentr.*, 1933, V. I, P. 2017).

The effect of starving silkworms on the weight of the cocoon and the sericin content, length, and denier of the cocoon filament has been investigated. Silk from a starved worm is richer in sericin and finer than normal. (Copied complete from *J. T. I.*, May, 1933, P. A238.) (S)

WOOL IN THE MERINO: GROWTH OF. J. E. Duerden, C. A. Murray, and P. S. Botha, *18th Rep. Director, Veterinary Services and Animal Industry, S. Africa*, 1932, Part II, P. 973–990.

Both the body weights and the monthly rate of growth of the wool show a direct response to the grazing conditions of the sheep. The investigation does not, however, allow of any seasonal influence being determined, apart from the pasturage conditions. In the groups selected no constant relationship holds between the body weight of the individual sheep and the fleece weight. There is no constant ratio between the body weight of a sheep and the length of the wool it produces. The results do not afford any decisive evidence of a more rapid growth during the first months after shearing in comparison with the growth during the later months. (Copied from *J. T. I.*, April, 1933, P. A178.) (S)

II. YARNS AND FABRICS

CLOTH FAULTS IN WEAVING: USE OF AN ANALYSIS. O. B. Sitzenhofer. *Tex. Mfr.*, April, 1933, P. 139.

A suggestion for the use of cloth inspector's analysis of quality in control in the weaving shed. (S)

DRAFTING AND DOUBLING: CONSIDERATIONS IN WORSTED. J. Dumville. *Tex. Mfr.*, April, 1933, P. 133.

Discussion of the pointing required in attaining a regular and parallel disposition of straight fibres and the blending effects of drafting and doubling. (S)

MILDEW: DEFECTS CAUSED BY. *Wool Rec.*, 1933, V. 43, P. 146–147.

The occurrence of mildew in cheeses of worsted yarn is discussed, and suggestions given for the level dyeing of the yarn. (S)

WARP STOP-MOTION: AN IMPROVED. Anon. *Tex. Mfr.*, April, 1933, P. 155.

A new method of giving a clear indication of position of the broken end. (S)

WOOL: DETERMINATION OF ACIDS IN. S. R. Trotman and G. N. Gee. *Am. Dye. Rept.*, May 8, 1933, P. 303. Reprinted from the *J. Soc. Dyers and Col.*, 1932, V. 48, P. 321.

The determination of acid in woolen goods, both undyed and dyed, is often a matter of considerable importance. There may be present sulfurous, sulfuric, hydrochloric, acetic or formic acids. Both sulfurous and sulfuric acids are found in stoved goods, while any of the acids mentioned may occur in dyed samples. The determination of acid is affected by the facts that wool has basic properties and adsorbs acids from their aqueous solutions. This acid is held tenaciously. (S)

WOOLEN CARDING MACHINE: CONTINENTAL TYPE OF. S. F. *Tex. Mfr.*, April, 1933, P. 136.

Type of set required for fine woolen yarns from short clean materials, angola blends, and flannel. (S)

WORSTED TOP QUALITIES. S. Kershaw. *Tex. Mfr.*, Jan., 1933, P. 4.

What is and what might be in worsted top qualities. The factor of fineness of fibre is particularly emphasized. (S)

III. CHEMICAL AND OTHER PROCESSING (NOT OTHERWISE CLASSIFIED)

AZO CHROMOPHORES. V. J. S. Petrus Blumberger. *Chem. Weekblad*, 1933, V. 30, P. 538–47; *Chem. Abs.*, 1932, V. 26, P. 5082.

The color changes of *o*-hydroxyazo dyes with OH ions as well as the changes of the aminoazo dyes with H ions (*Chem. Abs.*, V. 21, P. 3354) can be explained by "chromophore inversion." A great no. of examples are given to illustrate the theory. A new "auxochrome" group, NHNa, is added to those given earlier. The azo chromophore can be the only cause for the absorption of the visible part of the spectrum. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5543.) (W)

AZO DYE ANALYSIS: SUBSTITUTION OF A TITRATION WITH DICHROMATE INSTEAD OF IODINE IN THE DETERMINATION OF STANNOUS CHLORIDE IN. G. Ostrozhinskaya. *Anilin. Prom.*, 1931, No. 1, P. 18–20; *Chem. Zentr.*, 1932, V. I, P. 1301.

In analysis of azo dyes by the method of Knecht the excess $SnCl_2$ can be detd. by titration with dichromate instead of I_2 according to the equation: $3SnCl_2 + K_2Cr_2O_7 + 14HCl = 3SnCl_4 + 2KCl + 2CrCl_3 + 7H_2O$. Excess dichromate reacts with KI to liberate I_2 so that the blue starch iodine color serves as indicator. Add 0.5 g. of the dye to freshly boiled water in a small flask, displace the air by CO_2, add 40 cc. HCl (1.19) and 20–30 cc.

0.2 *N* $SnCl_2$ and titrate the excess $SnCl_2$ with dichromate. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5983.) (W)

AZO DYESTUFFS: APPLICATION OF THE INSOLUBLE. F. Bradshaw. *Tex. Mfr.*, 1933, V. 59, P. 159.

A brief historical outline of their development. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5543.) (W)

BASIC DYES: NEW FIXING AGENTS FOR. V. I. Minaev and B. P. Fedorov. *Anilin. Prom.*, 1931, No. 4–5, P. 4–10; *Chem. Zentr.*, 1932, V. I, P. 1442.

It is suggested that the mixt. of polychlorobenzenes which is produced in the prepn. of monochlorobenzene be used as a fixing agent for basic dyes in dyeing and printing according to a process analogous to that given in Ger. pat. 281,175. The dichlorobenzenes are first converted into chlorophenols and then heated in alk. soln. with S. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5982.) (W)

BLEACHING OF COTTON AND LINEN: CHAIN REACTIONS IN OXIDATION PROCESSES. H. Kauffmann. *Tex. Mfr.*, Jan., 1933, P. 28.

A translation of an article appearing in *Mell. Textilber.*, 1932, V. 65, P. 179. The bleaching and oxidising action of hypochlorites is being investigated by the use of mixtures of bleaching liquor with hydrogen peroxide or other substances. The function of intermediate products called activators is described. (S)

BLEACHING WITH HYDROGEN PEROXIDE—THE MODERN PRODUCT IN THE TEXTILE TRADES. I. E. Weber. *Chem. Trade J.*, 1933, V. 93, P. 153–5.

H_2O_2 produces a more permanent bleach than most other bleaching agents. An enhanced white is obtained in bleaching wool together with $Na_4P_2O_7$ and $Na_2C_2O_4$ or $H_2C_2O_4$. This method is mainly applicable to the steeping process. Silicate with a Na_2O: $3.2SiO_2$ ratio is better than water glass or metasilicate. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5546.) (W)

CHEMICAL ANALYSIS OF RAYONS. II. MICRODETERMINATION OF METALS IN COMMERCIAL RAYON YARNS. B. P. Ridge, Mary Corner and H. S. Cliff. *J. T. I.*, 1933, V. 24, P. 293–308T; cf. *Chem. Abs.*, 1931, V. 25, P. 5036; V. 27, P. 4679.

Three methods are described for detg. small amounts of Cu in rayons; a gravimetric method, in which the Cu is pptd. and weighed as thiocyanate; a catalytic method which depends on the fact that the reduction of ferric iron by $Na_2S_2O_3$ is catalyzed by the presence of Cu salts, the extent depending on the amount of Cu present; and a colorimetric method depending on the brown color developed by diethyldithiocarbamate. A modification of Knop's process for Fe is described. The metal present in the ferrous state is titrated with $K_2Cr_2O_7$ soln., with a soln. of diphenylamine in concd. H_2SO_4 as indicator. Considerable difficulty was experienced with Zn, the procedure finally selected for its detn. being pptd. by means of 8-hydroxyquinoline. The ashing of the samples is discussed. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5533.) (W)

IV. Research Methods and Apparatus

Analysis of α-Cellulose. W. M. Billing. *Plastic Products*, 1933, V. 9, P. 277.

Approx. 3-g. samples are oven-dried. Each sample is treated with 35 cc. of 17.5% NaOH, allowed to stand for 5 min., then macerated for 10 min., during which time 4 10-cc. portions of the NaOH are added. After 30-min. addnl. standing in a water bath 200 cc. water is added, the mixt. is well stirred and filtered on a fritted-glass funnel (11G2), the residue washed with 750 cc. water and sucked dry, allowed to stand in 40 cc. of 10% AcOH for 2 min., and again sucked dry, and finally washed with water until neutral to litmus. The dried residue is weighed as α-cellulose. All solns. and the water bath are carefully adjusted to 20°. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5963.) (W)

Combined Stapling Test: A Standard Form for the Cotton. Anon. *Tex. Mfr.*, April, 1933, P. 135.

A well arranged and complete form is presented for use in connection with the Baer Stapler. (S)

Micro-Comparator: A Simplified. *The Analyst*, Nov., 1933, P. 684–6.

The Micro-Comparator has been devised to facilitate the simultaneous comparison of two objects too large to be brought together in close proximity, for, with its special extension, the instrument covers a range of 30 cm. It thus enables a standard article to be rapidly compared with a sample. Any objects, such as seal impressions, typewritten letters, stamps, paper, textile fibres, wood, etc., can be easily compared, and a photographic record made of them with the aid of a micro-camera, which can be fitted to the apparatus. The instrument, which is mounted on a stand, consists of a telescopic tube which draws out on either side, giving it a range of one foot. In the centre of this tube is one which contains a low-power eyepiece. At either end of the main tube, which is fitted with four specially paired prisms, depends an arm into which low-power magnifiers (e.g. × 5) are fitted, and these can be independently focussed. The two halves of the field, viewed through the single eyepiece, appear in juxtaposition.

At present the magnification is confined to low powers, but the eyepiece and lenses, being of standard size, are interchangeable with the higher-power eyepieces and objectives ordinarily used on microscopes. The instrument can be adapted to the horseshoe type of microscope. (S)

Wool Fibre: Action of Electrolytes on. D. A. Wilson and N. E. Gordon. *J. Am. Chem. Soc.*, 1933, V. 55, P. 3896–7.

In the x-ray examination of wool, the pure fibre gives a very indistinct fibre diagram; when the wool is treated with certain electrolytes, two quite sharp and distinct rings appear; wool dyed industrially shows these two rings. It is suggested that the action of the electrolytes causes the wool protein to become cryst. to some extent and that these crystallites so formed are oriented along the fibre axis as evidenced by the character of the rings. These rings appear to be high orders of a period of 77.8 A. U. in length. (Copied complete from *Chem. Abs.*, 1933, V. 27, P. 5192.) (W)

Book Reviews

TEXTILES AND THE MICROSCOPE. By Edward R. Schwarz. McGraw-Hill Book Co., Inc., New York and London. Pp. 329. $4.00.

The leading authority on textile microscopy, micrometry and microanalysis in this country outlines in this volume in concise and usable form the results of his experience in the application of these sciences to textile research. It not only covers the fundamentals, and the methods of other fields of microanalysis that he has found to be applicable to the textile field, but provides the technician and research worker with very complete techniques, many of them originated by the author. He modestly states, however, that he aims to stimulate the reader to carry on original work rather than "to present him with all the minutiae of device and procedure." The chapters on fibre, yarn and fabric analysis will be found of equal value to the technician and to the research worker, but the author has wisely refrained from detailed discussion of fibre structure and identification, acknowledging that much remains to be done before this subject can be authoritatively and completely covered. The book is profusely illustrated and includes a valuable although not complete bibliography. The author is assistant professor of textile technology at Massachusetts Institute of Technology, a fellow of the Textile Institute (Eng.) and chairman of the abstracts committee and board of editors of U. S. Institute for Textile Research. (C)

DIE TEXTILMIKROSKOPISCHEN UNTERSUCHUNGEN IN DER PRAXIS. Jacques Klinger. Vienna. Sallmayersche Buchhandling. 1934. Pp. 93, 18 figures and 80 photomicrographs.

This treatise is written very evidently to give the general textile laboratory worker some insight into the valuable assistance which microscopy can contribute to many textile research problems. The author reverses the usual procedure and devotes the first part, or about two-thirds of the volume, to consideration of longitudinal mounts, fabric analysis, cross-sections, polarized light, darkfield work, microprojection, and drawing and photomicrography. The second part includes a discussion of the microscope, illuminants and accessory devices and a series of photomicrographs illustrating the text as a whole. This arrangement, while trying for the reader, is evidently adopted to reduce the cost of the book. The binding is also as inexpensive as possible. A novel expedient is used to caption the halftone illustrations. A series of abbreviations appear under each photomicrograph. These are also tabulated with an explanation of their significance. Possibly publication expense was lessened but this treatment certainly does not offset the added difficulty in studying the pictures intelligently. In spite of shortcomings as to physical make-up, the book will repay reading and it is amazing how much valuable information Mr. Klinger has packed into small compass. (S)